105th Congress, 1st Session – – – – – – – – – – – – – House Document 105–99

COOK INLET, ALASKA

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY (CIVIL WORKS), THE DEPARTMENT OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED SEPTEMBER 27, 1996, SUBMITTING A REPORT ON COOK INLET, ALASKA, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, PURSUANT TO PUBLIC LAW 104–303, SEC. 101(b)(2) (110 STAT. 3666–3667)

JUNE 20, 1997.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

COOK INLET, ALASKA

105th Congress, 1st Session – – – – – – – – – – – – – House Document 105–99

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U.S. GOVERNMENT PRINTING OFFICE

41–557 WASHINGTON : 1997

CONTENTS

List of Figures

List of Tables

APPENDICES ACCOMPANYING THE REPORT OF THE DISTRICT ENGINEER

(Only Appendices A, Part 3; B; C and D Printed)

LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
CIVIL WORKS
108 ARMY PENTAGON
WASHINGTON DC 20310-0108

REPLY TO
ATTENTION OF

04 JUN 1997

Honorable Newt Gingrich
Speaker of the House
of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

Section 101(b)(2) of the Water Resources Development Act of 1996, authorized a deep-draft navigation project at Cook Inlet, Alaska. The Secretary of the Army supports the authorization and plans to implement the project through the normal budget process.

The authorized project is described in the report of the Chief of Engineers dated September 27, 1996, which includes other pertinent reports and comments. These reports are in partial response to resolutions adopted by the Senate and House Committees on Public Works on April 27, 1970, and December 2, 1970, respectively.

The views of the State of Alaska, and the Departments of the Interior and Transportation are set forth in the enclosed communications.

The report of the Chief of Engineers describes the plan recommended by the reporting officers and the rationale for modifications made to that plan by the Chief of Engineers. The Secretary of the Army concurs in those modifications, noting that the plan recommended by the Chief of Engineers is the plan that maximizes net national economic benefits and is a plan that will better meet the needs of vessel operators under a wide range of weather and sea conditions. However, in describing the project depth, an additional depth of about 1.5 meters (4.9 feet) was inadvertently included to account for uncertainties in hydrographic surveys, dredging inaccuracies, and for advance maintenance. While it is appropriate to include such allowances in the determination of actual channel bottom excavation, it is not appropriate to include them in the authorized project dimensions. The 310 meter bottom width recommended by the Chief of Engineers is the correct channel width, as it did not include the additional width of about 30 meters (98 feet) on each side of the channel to account for similar uncertainties in hydrographic surveys and dredging, and for the instability of channel material. A final determination on the depth and width to be excavated will be made during preconstruction engineering and design.

The project provides for a deep-draft navigation channel with a length of about 2,000 meters (1.25 miles), a depth of about 11.5 meters (37.7 feet) below mean lower low water, and a bottom width of about 310 meters (1,017 feet). The project would provide for year-round access for deep-draft shipping into the Port of Anchorage, Alaska. No separable fish and wildlife mitigation is required. Based on October 1995 price levels, the total first cost of the project is about $5,700,000, of which about $3,705,000 would be Federal, and about $1,995,000 would be non-Federal.

The Office of Management and Budget advises that there is no objection to submission of the report to Congress. The project, as modified by the Chief of Engineers and the Secretary of the Army, is consistent with the program of the President. A copy of its letter is enclosed in the report.

Sincerely,

H. Martin Lancaster
Assistant Secretary of the Army
(Civil Works)

Enclosure

COMMENTS OF THE OFFICE OF MANAGEMENT AND BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

APR 17 1997

The Honorable Martin H. Lancaster
Assistant Secretary of the
Army for Civil Works
Pentagon - Room 2E570
Washington, D.C. 20310-0103

Dear Mr. Lancaster:

As required by Executive Order 12322, the Office of Management and Budget has completed its review of the Deep Draft Navigation Interim Feasibility Report and Environmental Assessment, Cook Inlet, Alaska, enclosed with your letter of September 27, 1996.

Your recommendations for this project are consistent with Administration policy. The Office of Management and Budget does not object to your submitting this report to Congress.

Sincerely,

T.J. Glauthier
Associate Director
Natural Resources,
Energy and Science

COMMENTS OF THE STATE OF ALASKA

STATE OF ALASKA

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
OFFICE OF THE COMMISSIONER

TONY KNOWLES, GOVERNOR

3132 CHANNEL DRIVE
JUNEAU, ALASKA 99801-7898

TEXT: (907) 465-3652
FAX: (907) 586-8365
PHONE: (907) 465-3900

May 21, 1996

Policy Review Branch
Policy Review and Analysis Division
Attn: CEW-AR (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3861

Dear Mr. David B. Sanford, Jr.:

Thank you for the opportunity to review and comment on the proposed report of the Chief of Engineers and the report of the District Engineer on Cook Inlet, Alaska.

I concur in the findings, conclusions and recommendations of the Alaska District Engineer and the proposed recommendations of the Chief of Engineers.

Sincerely,

Joseph L. Perkins

Joseph L. Perkins, P.E.
Commissioner

COMMENTS OF THE DEPARTMENT OF THE INTERIOR

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, D.C. 20240

ER 96/0336

JUL 31 1996

Mr. David B. Sanford, Jr.
Chief, Policy Review and Analysis Division
Policy Review Branch
ATTN: CECW-AR (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3861

Dear Mr. Sanford:

The Department of the Interior has completed its review of the Chief of Engineers Proposed Report, Deep Draft Navigation Interim Feasibility Report and Environmental Assessment for the Cook Inlet Near Anchorage, Alaska.

The reports incorporate fish and wildlife information provided to the Corps of Engineers during earlier planning stages. We have no further comments at this time.

Sincerely,

Willie R. Taylor

Willie R. Taylor, Director
Office of Environmental Policy
and Compliance

COMMENTS OF THE DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
United States Coast Guard

Commandant
United States Coast Guard

2100 Second Street, S.W.
Washington, DC 20593-0001
Staff Symbol: G-MOR-1
Phone: (202) 267-6134

16670

AUG 14 1996

Policy Review Branch
Policy Review and Analysis Division
ATTN: CECW-AR (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3861

Dear Sir:

This is in response to your letter of May 10, 1996, on behalf of Secretary Federico Peña, regarding the Deep-Draft Navigation Interim Feasibility Report and Environmental Assessment for Cook Inlet, Alaska.

We have no specific comments with respect to the Report. We do recommend the approval of the proposal for channel excavation. This is based on the Coast Guard's concerns about the problem with shoaling in the vicinity of Knik Arm shoal, which is a navigation hazard and also happens to result in a transit delay for deep-draft vessels.

If you have any questions, please contact LCDR Peter A. Jensen of my staff at the above number.

Sincerely,

R. E. BENNIS
Captain, U. S. Coast Guard
Chief, Office of Response
By direction of the Commandant

COOK INLET, ALASKA

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

CECW-PE (10-1-7a)

SUBJECT: Cook Inlet, Alaska

27 Sep 96

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report for deep-draft navigation improvements at Cook Inlet, Alaska. It is accompanied by the reports of the district and division engineers. These reports are in partial response to resolutions of the Committees on Public Works of the United States Senate and House of Representatives, adopted 27 April 1970 and 2 December 1970, respectively. The resolutions requested review of the reports of the Chief of Engineers on Copper River and Gulf Coast, Alaska, published as House Document 182, Eighty-third Congress, and on Cook Inlet and Tributaries, Alaska, published as House Document 34, Eighty-fifth Congress, and other pertinent reports, with a view to developing a comprehensive plan of improvement in the interest of deep-draft navigation for the south-central region of Alaska. Preconstruction engineering and design activities for this proposed project will be continued under the authority provided by resolutions cited above.

2. The reporting officers recommended the excavation of a channel 2,000 meters (6,562-feet) in length, along the southern flank of Knik Arm Shoal, following the present Fire Island navigation range (charted shipping route). The channel would be excavated to a depth of 13 meters (42.6 feet) below mean lower low water (MLLW), including 1.5 meters (4.9 feet), as an allowance for uncertainties in the analysis of channel stability. A channel width of 245 meters (804 feet) would be excavated. An additional width of 30 meters (98 feet), on each side of the channel, would be provided as an allowance for uncertainties in the analysis of channel stability. Vessel operators believe that the width of the channel is too narrow for winter ice conditions.

3. The Washington level review finds that the full transportation savings claimed for the 245-meter-wide channel may

not be realized due to the reluctance of vessel operators to use the channel during winter ice conditions. Letters in the report show that vessel operators believe that this channel width is too narrow. Pilots state that under these conditions they would wait for the tide and not use the proposed channel. The transportation savings claimed, therefore may not be fully achievable because of a combination of concerns raised by the vessel operators and pilots, such as, more hours of darkness, high winds, strong currents, and five months of heavy ice conditions during winter navigation. These natural elements often force vessels 216 to 241 meters (709 feet to 791 feet) in length crosswise in the channel.

4. A channel plan with a width of 310 meters (1,017 feet) which responds to user concerns on safe navigation during the winter ice season is identified in the feasibility report. An additional width of 30 meters, similar to that provided for the 245-meter-wide channel, would be provided on each side of the 310-meter-wide channel, as an allowance for uncertainties in the analysis of channel stability. Approximately one million cubic meters (1.3 million cubic yards) of excavated material from the channel would be discharged in open water about 2.2 nautical miles west of the excavation. The difference in net benefits claimed for the 245-meter-wide channel and the 310-meter-wide channel is small: $1,104,000 for the 245-meter-wide channel versus $1,056,000 for the 310-meter-wide channel. The optimum depth of both plans is at 13 meters (42.6 feet) below MLLW. There are no mitigation or non-Federal local service facility costs. The benefits claimed for the 245-meter-wide channel could be reduced by 15 to 25 percent because of the concerns raised by vessel operators and pilots. With a 15 percent reduction in benefits for the 245-meter-wide channel, the resulting net benefits for the 245-meter-wide channel and the 310-meter-wide channel would be $864,000 and $1,056,000 respectively, and the wider channel would be the NED plan. The final channel width will be refined during preconstruction engineering and design (PED) by the use of a field study of ship tracking through Differential Global Positioning Satellite (DGPS).

5. The estimated first cost of the 310-meter-wide channel, based on October 1995 price levels, is $5,700,000, of which $3,705,000 would be Federal and $1,995,000 (35 percent) would be non-Federal. The non-Federal costs includes 10 percent of the cost for the general navigation features (GNF) and an additional payment of 10 percent of cost of construction of the GNF, with interest, less credit for the value of lands, easements, rights-of-way and relocations (LERR), paid over a period not to exceed 30 years. Total average annual charges, based on a discount rate of 7.625 percent and a 50-year period for economic analysis are $742,000. Average annual benefits are estimated at $1,798,000 and the benefit-cost ratio is 2.4.

6. Washington level review indicates that the 310-meter-wide channel plan is technically sound, economically justified, and environmentally acceptable. The scope of the existing environmental assessment (EA) and findings of no significant impact (FONSI) covers a 310-meter-wide channel. The Port of Anchorage, in a letter dated 18 July 1996, expressed support and intent to cost-share in the plan. Also, shippers and pilots have confirmed their unanimous support for the plan. The proposed project complies with applicable U.S. Army Corps of Engineers planning procedures and regulations. Also, the views of interested parties, including Federal, State, and local agencies have been considered.

7. I concur in the findings, conclusions, and recommendations of the reporting officers, except that a reliable navigation channel width of 310 meters, along with the additional width of 30 meters on each side of the channel, as an allowance for uncertainties in the analysis of channel stability be provided. Accordingly, I recommend that the channel with a reliable navigation width of 310 meters, excavated to a depth of 13 meters below MLLW, along the southern flank of Knik Arm Shoal, be authorized with such modifications as in the discretion of the Chief of Engineers may be advisable. My recommendation is subject to cost sharing that is consistent with Administration policy and is made with the provision that, prior to implementation of the recommended project, the non-Federal sponsors shall enter into binding

agreements with the Federal Government to comply with the following requirements:

a. Provide operate, maintain, repair, replace, and rehabilitate at its own expense, the local service facilities in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

b. Provide all lands, easements, and rights-of-way, and perform or ensure the performance of all relocations determined by the Federal Government to be necessary for the construction, operation, maintenance, repair, replacement, and rehabilitation of the general navigation features;

c. Accomplish all removals determined necessary by the Federal Government other than those removals specifically assigned to the Federal Government;

d. Provide, during the period of construction, a cash contribution equal to 25 percent of the total cost of construction of the general navigation features for costs attributable to dredging to a depth in excess of 20 feet (6.096 meters) but not in excess of 45 feet (13.716 meters);

e. Repay with interest, over a period not to exceed 30 years following completion of the period of construction of the project, an additional 0 to 10 percent of the total cost of construction of general navigation features depending upon the amount of credit given for the value of lands, easements, rights-of-way, and relocations provided by the non-Federal sponsor for the general navigation features. If the amount of credit exceeds 10 percent of the total cost of construction of the general navigation features, the non-Federal sponsor shall not be required to make any contribution under this paragraph, nor shall it be entitled to any refund for the value of lands, easements, rights-of-way, and relocations in excess of 10 percent of the total cost of construction of the general navigation features;

f. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the general navigation features for the purpose of inspection, and, if necessary, for the purpose of operating, maintaining, repairing, replacing and rehabilitating the general navigation features;

g. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, replacement and rehabilitation of the project, any betterments, and the local service facilities, except for damages due to the fault or negligence of the United States or its contractors;

h. Keep, and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, and other evidence is required, to the extent and in such detail as will properly reflect total cost of construction of the general navigation features, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and local governments at 32 CFR Section 33.20;

i. Perform, or cause to be performed, any investigations for hazardous substances as are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the construction, operation, maintenance, repair, replacement, or rehabilitation of the general navigation features. However, for lands that the Government determines to be subject to the navigation servitude, only the Government shall perform such investigation unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

j. Assume complete financial responsibility, as between the Federal Government and the non-Federal sponsor, for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the construction, operation, maintenance, repair, replacement, and rehabilitation of the general navigation features;

k. To the maximum extent practicable, perform its obligations in a manner that will not cause liability to arise under CERCLA;

l. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for construction, operation, maintenance, repair, replacement, and rehabilitation of the general navigation features, and inform all affected persons of applicable benefits, policies, and procedures in connection with said act;

m. Comply with all applicable Federal and State laws and regulations, including, but not limited to, Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army;" and

n. Provide a cash contribution equal to 25 percent of the total historic preservation mitigation and data recovery costs attributable to commercial navigation that are in excess of

1 percent of the total amount authorized to be appropriated for commercial navigation.

7. The recommendation contained herein reflects the information available at this time and current departmental policies governing formulation of individual projects. It does not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program nor the perspective of higher review levels within the executive branch. Consequently, the recommendation may be modified before it is transmitted to the Congress as a proposal for authorization and implementation funding. However, prior to transmittal to the Congress, the sponsor, the Municipality of Anchorage; the State of Alaska; interested Federal agencies; and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

PAT M. STEVENS IV
Major General, USA
Acting Chief of Engineers

REPORT OF THE DISTRICT ENGINEER

Summary

The study summarized in the following report was conducted in response to similar resolutions of the United States Senate and House of Representatives, dated April 27, 1970, and December 2, 1970, requesting Corps of Engineers study of deep-draft navigation improvements in Southcentral Alaska. This report focuses on Cook Inlet, an estuary extending approximately 320 kilometers (km) southward from Knik and Turnagain Arms, by the Municipality of Anchorage, to the southern tip of the Kenai Peninsula. Deep-draft vessels call at oil terminals along the Kenai Peninsula, but the majority of deep-draft ships in Cook Inlet are approaching or departing from the Port of Anchorage on Knik Arm at the northern extreme of the inlet.

Shoals in Knik Arm require most deep-draft vessels to delay until higher stages of the tide. Tidal ranges in Knik Arm exceed 10 meters (m), the highest in the United States and second highest in all of the Americas. The shoals of primary concern are Fire Island Shoal, 12 nautical miles (nmi) from the Port of Anchorage, and Knik Arm Shoal, 6 nmi from the port. Fire Island Shoal was in years past a great concern. More recently the crest of the shoal has migrated southward and pilots have begun guiding ships north of the crest, where depths of 14.5 m are available at low tide.

Knik Arm Shoal is a mound-like glacial deposit. Waters in Knik Arm are highly turbid, and the Corps of Engineers presently removes about 170,000 cubic meters of silt from the maneuvering area at the Port of Anchorage. Surveys by the National Oceanic and Atmospheric Administration (NOAA) as recently as 1994, dating back to 1955, indicate that little change has occurred in the shape of the upper portion of Knik Arm Shoal in the last 40 years. The silt in suspension does not settle in the vicinity of Knik Arm Shoal because of strong tidal currents which regularly exceed 4 knots. North Point Shoal, a sandy shoal immediately north of Knik Arm Shoal, shows dramatic movement. North Point Shoal has retreated about one-half nautical mile in one place and advanced across Knik Arm for about one-half nautical mile in another, effectively closing the route past the north side of Knik Arm Shoal to deep-draft ships.

A computer simulation was developed of ships coming from Seattle and other ports of origin. Simulated arrivals at the Port of Anchorage agreed with records of actual arrivals provided by port officials. The simulations revealed that containerships regularly serving Anchorage are delayed 4 to 6 hours per passage because of Knik Arm Shoal's controlling

depth of 8.5 m at low tide. An excavated channel 11.5 m deep at low tide would reduce this delay by 2.5 to 3 hours per passage.

A channel alignment along the southern flank of Knik Arm is proposed, following the present Fire Island navigation range (charted shipping route). The 2,000-m-long channel would be excavated to 13.0 m depth at low tide, which allows 1.5 m for bottom irregularities and for uncertainties in the analysis of channel stability. A channel width of 245 m allows safe navigation in icy winter conditions. An additional 30 m on each side would be excavated (for a total width of 305 m) as an allowance for uncertainties in the analysis of channel stability. The initial excavation quantity is estimated as 848,600 cubic meters. The cost of the initial excavation is estimated at 1996 price levels to be $5.0 million. The cost of implementation in 1997 is estimated to be $5,342,000, of which a non-federal sponsor's share would be $1,870,000 (35 percent).

The proposed channel alignment shows no significant change in the period of record, but hydrographic change in nearby areas indicates a probability exists for a periodic maintenance requirement. The measured change closest to the proposed channel alignment and other physical evidence indicate that maintenance dredging more frequent than every 5 years has low probability. The dredging quantity at that frequency is unlikely to exceed 280,000 cubic meters. Sensitivity analysis regarding maintenance dredging indicates that periodic dredging at 10 years and 2 years would result in the same economically optimum excavation depth.

Average annual transportation savings achieved by the proposed channel improvement would exceed the average annual costs by $1,099,000 at current (1996) price levels, for a benefit/cost ratio of 2.6. Sensitivity analyses of depth and width reveal this plan to be the "NED Plan," or that alternative which maximizes net economic benefits for National Economic Development (NED). Environmental impacts appear to be acceptable, following review of the draft feasibility report by resource agencies and the general public. The State of Alaska and the Municipality of Anchorage have jointly sponsored this feasibility study. Both have expressed interest in sponsoring construction of the project. Both governments are legally and financially capable of providing non-federal sponsorship. The Municipality of Anchorage has submitted a letter of intent to act as the non-federal Sponsor for project implementation. Authorization and construction of the NED Plan for a channel excavation at Knik Arm Shoal are recommended.

Pertinent Data

Navigation Improvement at Knik Arm Shoal
Cook Inlet, Alaska

Geometric Characteristics of the Recommended Plan

Channel location	south flank of Knik Arm Shoal, 6 nmi west of the Port of Anchorage
Channel length	2,000 m
Channel width (navigation)	245 m
Channel width (excavated)[a]	305 m
Channel bottom elevation (navigation)	-11.5 m
Channel bottom elevation (excavated)[a]	-13.0 m
Channel side slopes	1 vertical: 4 horizontal
Channel excavation quantity	848,600 m^3

Disposal area location	0.5 nmi north of North Point, Fire Island, open water of Knik Arm
Disposal area dimensions	1/2 x 1 nmi
Disposal area size	171.5 hectares
Disposal area depth	to 35 m at MLLW

Construction Costs of the Recommended Plan

	Federal	Non-federal	Total
Initial costs at 1997 prices[b]	$4,006,000	$1,336,000	$5,342,000
Reimbursement	-534,000	534,000	
Final cost	$3,472,000	$1,870,000	$5,342,000

Total NED[c] costs (at 1996 prices)	$5,036,000
NED investment cost (including interest during construction)	$5,118,000
Equivalent annual NED investment cost (7.75 %/yr, 50 years)	$406,000
Average annual NED maintenance cost	$264,000
Total average annual cost	$670,000
Average annual NED benefits	$1,769,000
Net annual NED benefits	$1,099,000
Ratio of NED benefits to NED costs	2.6

[a] Additional excavation to allow for shoaling between dredgings.
[b] Includes estimated price changes at earliest possible implementation.
[c] National Economic Development (NED) costs must be offset by NED benefits for feasibility.

Conversion Factors

SI (METRIC) TO ENGLISH (INCH-POUND) UNITS OF MEASUREMENT

SI (metric) and nautical units of measurement are used in this report. These can be converted to English units as follows:

Multiply	By	To obtain
Celsius degrees (°C)	*	Fahrenheit degrees (°F)
centimeters (cm)	0.393701	inches (in)
cubic meters (m^3)	1.307951	cubic yards (yd^3)
hectares (ha)	2.471054	acres (ac)
kilograms (kg)	2.204623	pounds (lb)
kilometers (km)	0.539967	miles (nautical, nmi)
kilometers (km)	0.621371	miles (U.S. statute, mi)
knots (nautical miles per hour, kts)	1.150758	miles per hour
meters (m)	3.280840	feet (ft)
meters (m)	1.093613	yards (yd)
nautical miles (nmi)	1.150758	miles (U.S. statute, mi)

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* To obtain Fahrenheit (°F) temperature readings from Celsius (°C) readings, use the following formula: °F = (9/5)(°C + 32).

Glossary

Abbreviations, Acronyms, and Technical Terms

ADCED = Alaska Department of Commerce and Economic Development
ADCP = acoustic Doppler current profiler, an instrument for measuring the speed of water currents
ADOT&PF = Alaska Department of Transportation and Public Facilities
AEC = Alaska Engineering Commission (historical)
AIDEA = Alaska Industrial Development and Export Authority
AOML = Atlantic Oceanographic and Meteorological Laboratory (of the Corps of Engineers)
cm = centimeter(s)
CTD = conductivity-temperature-depth sensor, a device that measures these three characteristics of water
DGPS = Differential Global Positioning System, an improved form of GPS (see below)
dwt = deadweight ton(s)
ECDIS = electronic chart display
ER = Engineering Regulation
ft = foot, feet
ft^3/s = cubic feet per second
GPS = Global Positioning System, a system of navigation using electronic distance measurements to satellites in orbit
ha = hectares
km = kilometer(s)
kts = knots (nautical miles per hour)
L = liter(s)
m = meter(s)
m^3 = cubic meter(s)
m^3/s = cubic meters per second
mg/L = milligrams per liter
mi = mile(s)
MLLW = mean lower low water
mm = millimeter(s)
NED = National Economic Development; a measure of change in the economic value of the national output of goods and services resulting from a project
NEPA = National Environmental Policy Act (of 1969)
nmi = nautical mile(s)
NOAA = National Oceanic and Atmospheric Administration
OBS = optical backscatter, a method of measuring suspended sediment concentration in water
POL = petroleum, oils, and lubricants
Ro/Ro = roll-on, roll-off; a type of freight container that can be rolled on and off a ship
TOTE = Totem Ocean Trailer Express, a freight company
USACE = U.S. Army Corps of Engineers

Acknowledgments

The investigations summarized in this report were conducted primarily by the staff of the Alaska District, U.S. Army Corps of Engineers, in Anchorage, Alaska. The principal investigator was Dr. Orson P. Smith of the Project Formulation Section in the Civil Works Branch, Engineering Division of the Alaska District.

Economic investigations and analyses were performed by Mr. Richard Geiger with the aid of Ms. Janis Kara, Ms. Sofia Troutman, and Ms. Juanita Gwin of the Economics Section, Civil Works Branch. Channel design computations and graphical presentations were accomplished by Mr. Randy Bowker and Mr. Jim Fuhrer of the Hydraulics and Hydrology Section, and Mr. Bart Lane of Project Formulation Section, Civil Works Branch. Mr. Ron Cothren, on temporary assignment to Project Formulation Section from the University of Alaska Anchorage, and Ms. Barbara Reilly of the Geotechnical Branch performed field measurements of water properties and bed material characteristics. Ms. Lizette Boyer of Environmental Resources Section, Civil Works Branch, coordinated the participation of the U.S. Fish and Wildlife Service and prepared the Environmental Assessment. Ms. Carolyn Rinehart of Project Formulation Section and Ms. Diane Walters of Environmental Resources Section, Civil Works Branch, edited the main report and its appendixes and the Environmental Assessment.

Acoustic Doppler current profiler (ADCP) measurements and analysis were accomplished with the assistance of Mr. Troy Nelson, Ms. Terri Prickett, and Mr. Trap Puckette of the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, Mississippi.

Mr. Harvey Smith and Mr. Skip Barber of the Alaska Department of Transportation and Public Facilities provided vessel support and data collection assistance.

Data necessary for economic analyses were graciously provided by the Port of Anchorage, Port MacKenzie, Sea-Land Service, Totem Ocean Trailer Express, and the Southwest Alaska Pilots Association. Helpful comments were provided by these and other maritime interests at a series of coordination meetings hosted periodically by the Port of Anchorage throughout the study.

The support of the National Oceanic and Atmospheric Administration (NOAA), Pacific Marine Center, and the NOAA ship *Rainier* is gratefully acknowledged for providing vessel services, sea bottom samples, and hydrographic survey data critical to the conclusion of the study.

Water samples from Cook Inlet were analyzed by Dr. Sathy Naidu and Dr. Bruce Finney of the University of Alaska Fairbanks, Institute of Marine Science.

Golder Associates, Inc., accomplished geophysical surveys and geotechnical sampling and testing under contract to the Alaska District. LCMF, Ltd., accomplished hydrographic surveys and analysis of hydrographic change and supported ADCP and geophysical field measurements.

These investigations were conducted under the direction of Mr. Claude V. Vining, Chief, Engineering Division; Mr. Kenneth E. Hitch, Chief, Civil Works Branch; Mr. Carl Stormer, Chief, Project Formulation Section; Mr. Carl E. Borash, Chief, Hydraulics and Hydrology Section; Mr. Andrew Miller, Chief, Economics Section; and Mr. Guy R. McConnell, Chief, Environmental Resources Section.

Commander and District Engineer of the Alaska District during this study was Colonel Peter A. Topp, Corps of Engineers.

DEEP-DRAFT NAVIGATION INTERIM FEASIBILITY REPORT
COOK INLET, ALASKA

1. INTRODUCTION

1.1 Study Authority

The investigations summarized in this report were undertaken in partial response to similar resolutions of the Committees on Public Works of the United States Senate and House of Representatives, adopted April 27, 1970, and December 2, 1970, respectively. The House committee resolution read:

> *Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports of the Chief of Engineers on Copper River and Gulf Coast, Alaska, published as House Document Numbered 182, Eighty-third Congress, and on Cook Inlet and Tributaries, Alaska, published as House Document Numbered 34, Eighty-fifth Congress, and other pertinent reports, with a view to developing a comprehensive plan of improvement in the interest of deep-draft navigation for the Southcentral Region of Alaska.*

1.2 Federal Interest

The Federal interest in public works for navigation is derived from the commerce clause of the U.S. Constitution and is limited to the navigable waters of the United States. Federal navigation improvements on those waters must be justified as being in the general public interest and must be open to the use of all on equal terms. Improvements such as channels, jetties, breakwaters, locks, dams, maneuvering basins, and ice control measures may be eligible for Federal participation as general navigation features of waterway projects. Special navigation works may also be in the Federal interest, such as removal of wrecks or obstructions, snagging and clearing for navigation, or drift and debris removal. Facilities to accommodate vessels or load and unload cargo and passengers, such as docks, ramps, or floats, are the responsibility of non-federal interests. This is so even though these facilities may be necessary to achieve the benefits of the Federal project. Design and construction of aids to navigation, such as buoys, ranges, lights, or channel markers, are the responsibility of the U.S. Coast Guard.

1.3 Federal Policies and Procedures

The Corps of Engineers must follow administrative policies expressed in various Engineering Regulations (ER's) and other Department of the Army memoranda. The most pertinent of these regulations is ER 1105-2-100, "Guidance for Conducting Civil Works Planning Studies." This regulation summarizes and interprets relevant statutes, congressional resolutions, executive directives, and other regulations regarding studies of this type and the criteria that must be applied in them.

Prospective projects must be evaluated for their economic feasibility and environmental acceptability as well as for their engineering soundness. The Water Resource Council's publication *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* is used in these evaluations. Economic feasibility is determined by evaluating the National Economic Development (NED) benefits of the project alternatives. Chapter II of the Principles and Guidelines, "National Economic Development Benefit Evaluation Procedures," is used for this purpose. Economic feasibility is established if, within these guidelines, the NED benefits achieved by a solution fully offset the long-term costs of its implementation.

Environmental evaluation of proposed navigation improvements must follow Chapter III of the Principles and Guidelines, "Environmental Quality (EQ) Evaluation Procedures," as well as other Federal, State, and local statutes and regulations. Requirements of the National Environmental Policy Act of 1969 (NEPA), as amended, prevail in these considerations. This report includes an Environmental Assessment, which cites the full range of other laws, regulations, and policies which apply.

1.4 Reconnaissance Study Findings and Conclusions

A federally funded reconnaissance study was initiated in November 1991. The "Deep Draft Navigation Reconnaissance Report, Cook Inlet, Alaska," was published in April 1993. This study investigated all of Cook Inlet in terms of deep-draft navigation needs and provided an extensive description of physical conditions in all areas of the waterway. The study found a Federal interest in a channel improvement at Knik Arm Shoal in the Knik Arm of upper Cook Inlet and concluded that the feasibility of this improvement should be investigated further. The Alaska Department of Transportation and Public Facilities (ADOT&PF) was found to be a fully qualified and willing non-federal sponsor of the feasibility study. A cost-shared feasibility study was recommended based on the apparent economic feasibility and environmental acceptability of dredging a channel across Knik Arm Shoal 300 meters (m) wide and 12 m deep at low tide. The reconnaissance study estimated that this alternative would cost about $2.3 million to construct and have a benefit-to-cost ratio of 2.3. Maintenance dredging was predicted to be necessary every other year after initial dredging, even with extra width and depth allowances for accumulation of material.

1.5 Sponsorship

The Water Resources Development Act of 1986 (P.L. 99-662), as amended, specifies that a non-federal sponsor must agree to the scope and schedule of feasibility studies for navigation projects undertaken by the Corps. The act further specifies that the sponsor must pay half the study cost. A maximum of half the sponsor's cost share may be in-kind contributions to the study. An "Agreement Between the United States of America and the State of Alaska for Navigation Improvements in Cook Inlet, Alaska - Feasibility Study" was executed on January 6, 1994. The ADOT&PF arranged for half of the non-federal share of the study funds to be provided by the Municipality of Anchorage by separate agreement. The ADOT&PF and Municipality of Anchorage (Port of Anchorage) both provided significant in-kind contributions to the field data collection, data analyses, and design of project features.

1.6 Scope of the Feasibility Study

The geographical scope of the study includes Knik Arm of upper Cook Inlet, with particular focus on the reach of Knik Arm from Fire Island to Point Woronzof, which surrounds Knik Arm Shoal. The technical scope of the study was the product of negotiations that led to the cost-shared agreement discussed above. The behavior of bed materials in Knik Arm near Knik Arm Shoal was studied in field measurements conducted during 1994. A numerical model of ship transits of Cook Inlet was applied to determine time savings due to channel dredging alternatives at Knik Arm Shoal. An environmental assessment was prepared regarding proposed open-water disposal of dredged material at a site approximately 3 kilometers (km) west of the proposed channel improvement.

1.7 Coordination With Public and Private Interests

Coordination of study efforts was continuous throughout the feasibility study in the form of correspondence and personal communications between the principal investigator, other study participants, the ADOT&PF, the Port of Anchorage, and various public and private interests. Coordination meetings were held at the Port of Anchorage at which representatives of the study sponsors and the Alaskan shipping industry were informed of progress. Totem Ocean Trailer Express, Inc.; Sea-Land Service, Inc.; and the Southwestern Alaska Pilots Association were particularly helpful in providing detailed data about ships, cargoes, and operational difficulties related to conditions at Knik Arm Shoal and the Port of Anchorage.

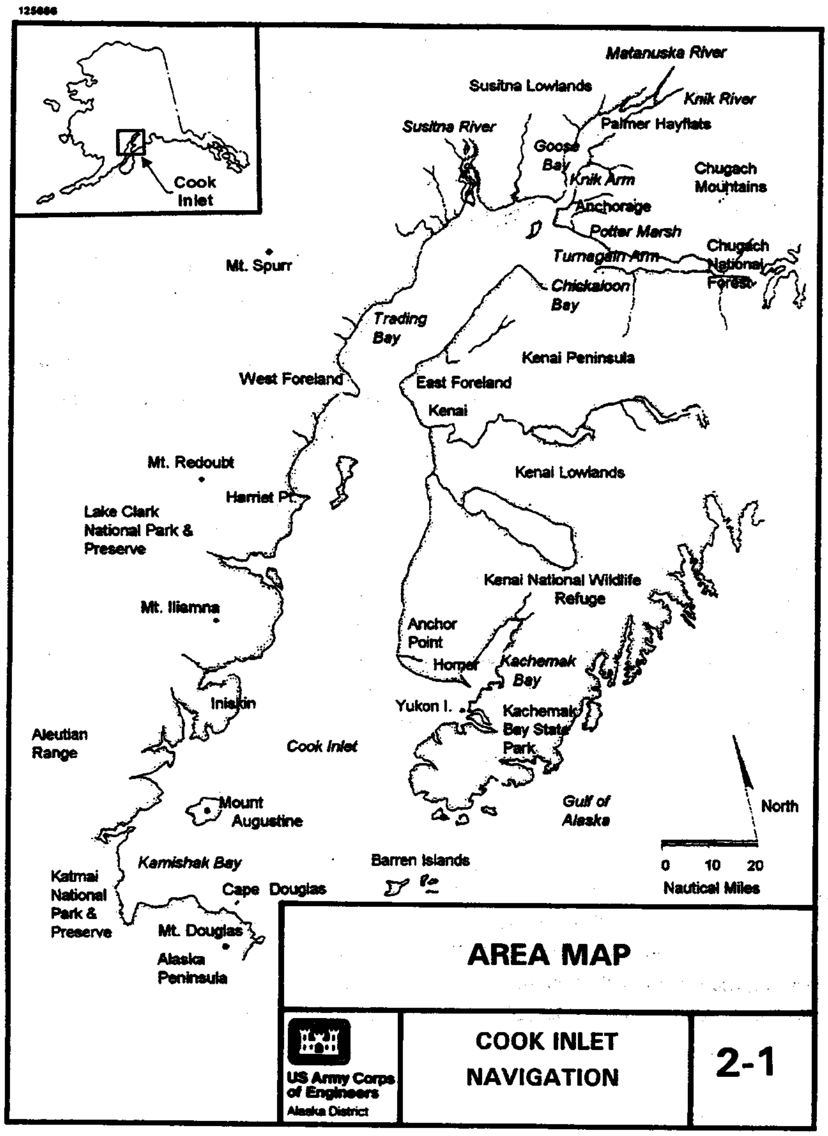
2. PHYSICAL SETTING

2.1 Geography

Cook Inlet is a large estuary on the southcentral coast of Alaska, bordered on three sides by rugged mountains, tidal flats, marshlands, and rolling lowlands. Figure 2-1 shows the inlet and the geologic features that surround it. The inlet is approximately 300 km long, from the Knik and Turnagain Arms in the north to the southern tip of the Kenai Peninsula. The inlet includes four major bays: Knik and Turnagain Arms and Kachemak and Kamishak Bays. Kamishak Bay, located in the southwest end of Cook Inlet, is nearly 40 km long and 40 km wide at its mouth. Kachemak Bay, in the southeast end of the inlet, is about 56 km long. Both Knik and Turnagain Arms, at the northern extreme of Cook Inlet near Anchorage, are more than 60 km from their mouths to the limits of their tidelands. Kachemak Bay and Knik and Turnagain Arms are narrow, having widths generally less than 8 km.

Cook Inlet, oriented northeast by southwest, is bounded on the southwest by the volcanically active Aleutian Mountains, on the northeast by the Alaska Range, on the northwest by the Talkeetna Mountains, and on the east by the Chugach and Kenai Mountains. It is bordered by extensive tidelands, which rise to the piedmont plains and the Kenai and Susitna lowlands. The Kenai Lowlands extend 50 to 60 km from Cook Inlet to the base of the Kenai Mountains. The Susitna lowlands lie at the head of the inlet, between the Talkeetna Mountains and the Alaska Range. On the west side of the inlet, the piedmont plains extend westward to the base of the Alaska Range. The East and West Forelands extend toward each other, creating a constriction that divides the inlet into upper and lower parts. The inlet's width increases from about 30 km in the north near the confluence of Knik and Turnagain Arms to more than 80 km in the south near its opening to the Gulf of Alaska and the Pacific Ocean.

The shores of Cook Inlet are home to nearly half of Alaska's population. Anchorage, the State's largest city and center of transportation, is located at the inlet's northeast end, between Knik and Turnagain Arms. The Cook Inlet region encompasses a wealth of natural resources, wildlife, and scenery. Lake Clark and Katmai National Parks and Preserves, the Kenai National Wildlife Refuge, Kachemak Bay State Park, and the Chugach National Forest surround the inlet. The State of Alaska owns most submerged lands within 5 km of


125686
Cook Inlet
Matanuska River
Susitna Lowlands
Knik River
Palmer Hayflats
Susitna River
Goose Bay
Knik Arm
Chugach Mountains
Anchorage
Potter Marsh
Turnagain Arm
Chugach National Forest
Mt. Spurr
Chickaloon Bay
Trading Bay
Kenai Peninsula
West Foreland
East Foreland
Kenai
Mt. Redoubt
Kenai Lowlands
Harriet Pt.
Lake Clark National Park & Preserve
Kenai National Wildlife Refuge
Mt. Iliamna
Anchor Point
Homer
Kachemak Bay
Iniskin
Yukon I.
Kachemak Bay State Park
Aleutian Range
Cook Inlet
Mount Augustine
Gulf of Alaska
North
Kamishak Bay
Barren Islands
0 10 20
Nautical Miles
Katmai National Park & Preserve
Cape Douglas
Mt. Douglas
Alaska Peninsula
AREA MAP
US Army Corps of Engineers
Alaska District
COOK INLET NAVIGATION
2-1

the Cook Inlet coast, as well as most intertidal lands (the area between the lines of mean high and mean low tide).

The majority of fresh water enters the inlet from three rivers at its northern end. The Matanuska, Susitna, and Knik Rivers contribute nearly 70 percent of the fresh water discharged annually into the inlet (Gatto 1976). Table 2-1 presents streamflow statistics for these three rivers. These and other glacier-fed streams throughout the inlet basin contribute millions of tons of sediment annually to the inlet.

TABLE 2-1.–*Average, maximum, and minimum recorded flows for the Matanuska, Knik, and Susitna Rivers*

River	Gauge location	Average flow (m^3/s)	Maximum flow (m^3/s)	Minimum flow (m^3/s)
Matanuska	Palmer	108	2,325	7
Knik	11 km S. of Palmer	19	10,166	7
Susitna	2.4 km downstream of the Yentna River	1,437	8,835	142

Source: USGS, water years 1991, 1988, and 1986.

Knik Arm, at the head of upper Cook Inlet, is the focus of the current study, since its lower reach includes the approach route of deep-draft ships bound for the Port of Anchorage or adjacent port facilities. Figure 2-2 shows the shoreline and general bathymetry of the lower reach of Knik Arm, from just above Anchorage to its confluence with Turnagain Arm. The Anchorage Bight is the local name for the shoreline indentation on the eastern shore from Point Woronzof to Cairn Point. The municipal port facilities are located just south of Cairn Point at the northern end of the Anchorage Bight. Existing and proposed port facilities in the Anchorage area are described in section 4 of this report.

Point Woronzof is the site of a secondary sewage treatment plant which discharges effluent into Knik Arm. Point Woronzof is also the terminus of submarine power cables of the Chugach Electric Association, Inc. Point Campbell is near the end of the main runway for Anchorage International Airport, and most flights approach and depart over Knik Arm at this point. A complex of shoals, beginning west of Fire Island with Fire Island Shoal and including North Point Shoal, Knik Arm Shoal, and Woronzof Shoal, affects deep-draft ships approaching or leaving the port.

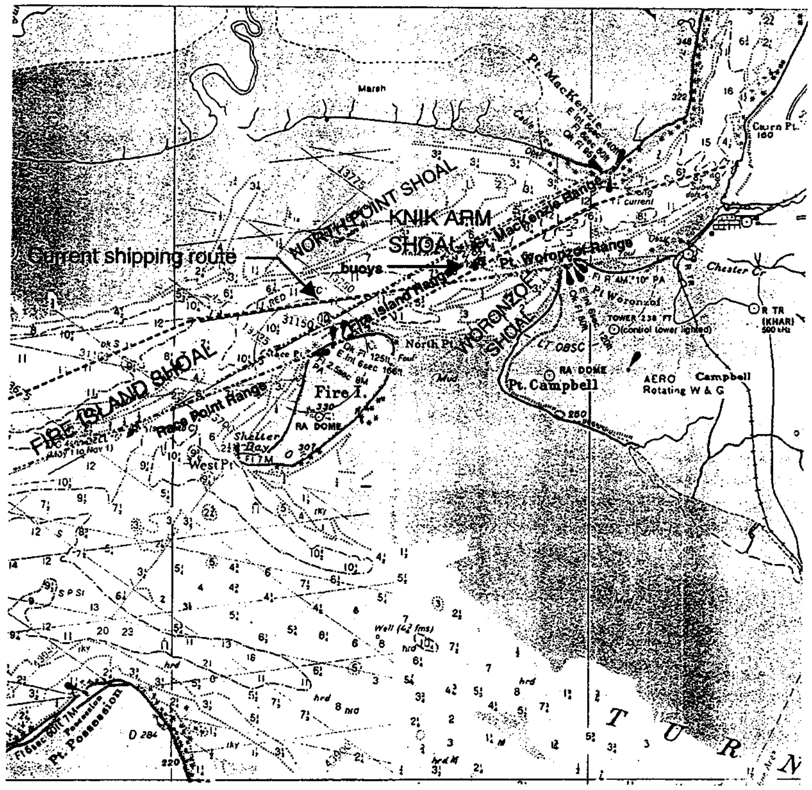


FIGURE 2-2.--Knik Arm shoreline and general bathymetry, with current shipping route.

2.2 Climate

The Cook Inlet area is in a transition zone between Alaska's maritime and interior climates. The lower inlet has a more maritime climate, with cooler summers and milder winters than in the upper reaches of the inlet. A comparison of temperatures between two cities located at opposite ends of the inlet demonstrates the differing climates. Anchorage, at the head of the inlet, has an average winter temperature of -9 °C and a summer average of 13 °C. Homer, near the southern end of the inlet, has averages of -7 °C in winter and 10 °C in the summer.

The maritime climate causes an increase in the total annual precipitation toward the mouth of the inlet. Anchorage, located at the north end of the inlet, receives an average of only 36 centimeters (cm) of precipitation annually. Kenai, midway up the east side, receives 48 cm. Homer, near the southern end, receives 56 cm, while Iniskin, directly across the inlet from Homer, receives 185 cm (Gatto 1976). The lower part of the inlet receives more winter precipitation in the form of rain and less as snowfall than the upper portion. However, the upper portion of the inlet receives slightly more precipitation in the summer. Fifty percent of the annual precipitation in the basin falls between July and October. The driest period of the year is typically between January and May.

The mountains surrounding the inlet basin greatly affect the local weather. Total annual precipitation is reduced in the inlet by the Chugach and Kenai Mountains, which block the moisture-laden air arriving from the Gulf of Alaska. The mountain ranges on the east and west sides of the inlet funnel winds from the north and south. As a result, winds from the north prevail in the fall, winter, and spring, and southerly winds prevail in the summer throughout the basin. Highest windspeeds occur in late autumn and winter.

2.3 Geology

2.3.1 Cook Inlet Area.

Tectonism, or plate movement, is responsible for creating the basin and mountain ranges, active volcanoes, and earthquakes common to the area. Cook Inlet is an elongated depression of the earth's crust between parallel faults and is known in geological terms as a "graben." The inlet lies between the Chugach, Bruin Bay, and Castle Mountain Faults.

The basin was created by the folding of the earth's crust that occurred during the Tertiary period, which began approximately 70 million years ago. The major topographic elements of the area were established by the end of the Tertiary period about 2 million years ago. The major highlands, including the Chugach, Talkeetna, and Alaska mountain ranges, had been raised. The Cook Inlet-Susitna Basin existed much as it is today. Since this period, several major glaciations have altered the landscape of the Cook Inlet region. During the Pleistocene age, 2 million to 10,000 years ago, glaciers pushed beyond the mountain fronts into the lowlands, depositing sediment and debris hundreds of meters thick. As the glaciers receded, Cook Inlet assumed its present form. The lowlands, no longer well drained, are covered with numerous lakes and swamps. Ice scouring left the harder rock ridges, while depositing the scoured, softer sediment on the lower valleys.

The mouths of the Matanuska, Knik, and Susitna Rivers are located in the upper portion of the inlet. Table 2-1 lists the average, maximum, and minimum recorded flows of these rivers. These glacier-fed rivers carry a heavy sediment load, particularly during summer. For example, the rivers entering Turnagain Arm discharge nearly 3 million tons of sediment annually, while the rivers entering Knik Arm discharge about 20 million tons (Gatto 1976). This sediment continues to fill the upper inlet and is carried into the southern inlet and out into the Gulf of Alaska.

Volcanism is produced by plate subduction. The Pacific plate in Southcentral Alaska is being drawn under the North American plate all along the southern coast of Alaska. Five volcanoes border Cook Inlet on the west side: Douglas, Augustine, Iliamna, Redoubt, and Spurr. These volcanoes, classified geologically as andesitic, erupt more violently than the basaltic intrabasin volcanoes of the Pacific plate. All but Douglas have been active in historic time.

Southern Alaska and the Aleutian chain are in one of the world's most active seismic zones. The Alaska seismic zone is a part of the vast belt of seismic activity, or "ring of fire," that circumscribes the entire Pacific Ocean Basin. Between 1899 and 1965, nine Alaska earthquakes equaled or exceeded 8 on the Richter scale, and more than 60 equaled or exceeded 7. The Cook Inlet region is in seismic risk zone 4, defined as areas susceptible to great earthquakes with magnitudes 6.0 to 8.8 and where major structural damage will occur.

At 5:36 p.m. Alaska Standard Time on Good Friday, March 27, 1964, an earthquake centered approximately 113 km west of Anchorage violently rocked Southcentral Alaska for nearly 5 minutes. Just after it occurred, the earthquake was estimated as having a magnitude of 8.5 on the Richter scale. Today's estimates put the magnitude at greater than 9.0. The energy released by the Good Friday earthquake was half again as much as the magnitude-8.3 earthquake that devastated San Francisco in 1906 (Wilson and Tørum 1968). The Alaska earthquake caused uplift and subsidence that affected areas in and around Cook Inlet. In addition, substantial horizontal movement of the land was documented. An axis along which the land did not sustain any substantial horizontal movement lies roughly in line with Knik Arm in upper Cook Inlet. Land to the north of this axis moved to the northwest, while land south of the axis moved to the south-southeast.

These massive earth movements generated a train of tsunami waves that surged across the Pacific Ocean, causing damage as far south as California. Landslides and submarine slumping of unstable glacial deltas created waves that caused localized damage along Alaska's southcentral coastline. Whittier, Valdez, Seward, Kodiak, and other communities on the steep shorelines of Prince William Sound and the Gulf of Alaska suffered heavy damages. Tsunami wave heights reached up to 20 m. Cook Inlet saw relatively minor tsunami energy. Virtually none was reported in the upper inlet. The tsunami lost energy to reflection, refraction, and diffraction as it entered the mouth of Cook Inlet. The wave also lost energy as it moved up the inlet to friction and to the powerful ebb currents of the outgoing spring tide (Wilson and Tørum 1968).

2.3.2 Geology of Knik Arm.

Geophysical measurements and geotechnical sampling and testing were conducted in Knik Arm between Point Woronzof and Fire Island in the vicinity of Knik Arm Shoal as a part of this study. The bedrock beneath Anchorage is known to be Tertiary sedimentary rock. This rock forms a wedge to the east that laps up against the Mesozoic-Era (220 to 70 million years ago) metamorphic rock of the Chugach Mountains. Bedrock beneath Anchorage is 100 m or more beneath the surface and is nowhere exposed (Updike *et al.* 1984).

The form and major characteristics of Knik Arm are due to glaciations during the Pleistocene Epoch (2 million to about 10,000 years ago). Sediments beneath Anchorage and Fire Island were deposited during periods of glacial retreat during the late Pleistocene. The last glacial advance past Fire Island, known as the Skilak Stade of the Naptowne glaciation, occurred about 15,000 years ago. Sediments were deposited as moraines, glacial deltas, and outwash flood plains as the glacier retreated. This glacial retreat may have deposited a series of arc-shaped moraines across Knik Arm, with cobbles and boulders from the glacier terminus interspersed in finer-grained sediments.

A period of still water probably followed the retreat of the Skilak Stade in the lower reach of Knik Arm, either as an estuary connected to the rest of Cook Inlet or as a lake dammed by a glacial moraine. The well-known Bootlegger Cove formation of silt and clay, which is widespread beneath the west Anchorage area, was probably deposited during this time. The formation is interspersed with fingers of coarser material (Updike and Ulery 1986). Since retreat of the glaciers, the Anchorage area has experienced isostatic rebound, as well as tectonic uplift, which is responsible for the formation of the bluffs along most of the shoreline of Knik Arm. The effects of tidal currents and occasional periods of high water and extreme wave action have caused these bluffs to retreat steadily and to contribute additional sediments to the waters of Knik Arm.

A geophysical survey of central Knik Arm over an area surrounding Knik Arm Shoal was performed as a part of this study in June 1994.. These measurements were supplemented with testing of surface samples and samples from seven boreholes made in August 1994. The measurements revealed a variety of surface features of the seabed, including sand waves 3 to 5 m high with a wavelength of 80 to 100 m in deeper water west of Knik Arm Shoal. Sand waves 1 to 2 m high with wavelengths of 30 to 50 m were observed north of Knik Arm Shoal at its confluence with the sandy North Point Shoal. Bed samples in this area were of poorly graded (*i.e.*, nearly uniform) medium sand, with median grain diameters of 0.3 to 0.5 mm. Subsurface acoustic reflections west of Knik Arm Shoal indicate 2 to 5 m of sand lies over coarser material, typical of the rest of the survey area.

The surface of the crest and southern flank of Knik Arm Shoal was of the same chaotic acoustic reflection pattern, which extended 10 to 20 m beneath the surface. Samples in this area often were impossible to collect even with spring-loaded sampling devices or were only small quantities of medium sand and rounded gravel. This reflection pattern is characteristic of cobbles and boulders interspersed with widely-graded finer material, which is typical of many Alaskan glacial deposits commonly called "glacial till." The distinct hyperbolic patterns of boulders larger than 0.5 m were not detected in the acoustic reflection data nor were any larger rocks encountered in the boreholes, indicating that larger boulders are not widespread within the survey area. The geophysical measurements and geotechnical sample tests are discussed in greater detail in appendix A (part 2) of this report.

2.4 Oceanography

2.4.1 Cook Inlet.

Cook Inlet above the East and West Forelands is a shallow basin, with depths generally less than 30 m, as shown in figure 2-3. Knik Arm averages 15 m in depth for about half of its length and then rapidly shallows to a tidal flat. Turnagain Arm shallows within the first 16 km to a large tidal flat cut by many tidal channels. Tidal marshes are prevalent around the mouth of the Susitna River; in Chickaloon, Trading and Goose Bays; in the Palmer Hay Flat at the head of Knik Arm; and in Potter Marsh within the Anchorage coastal area.

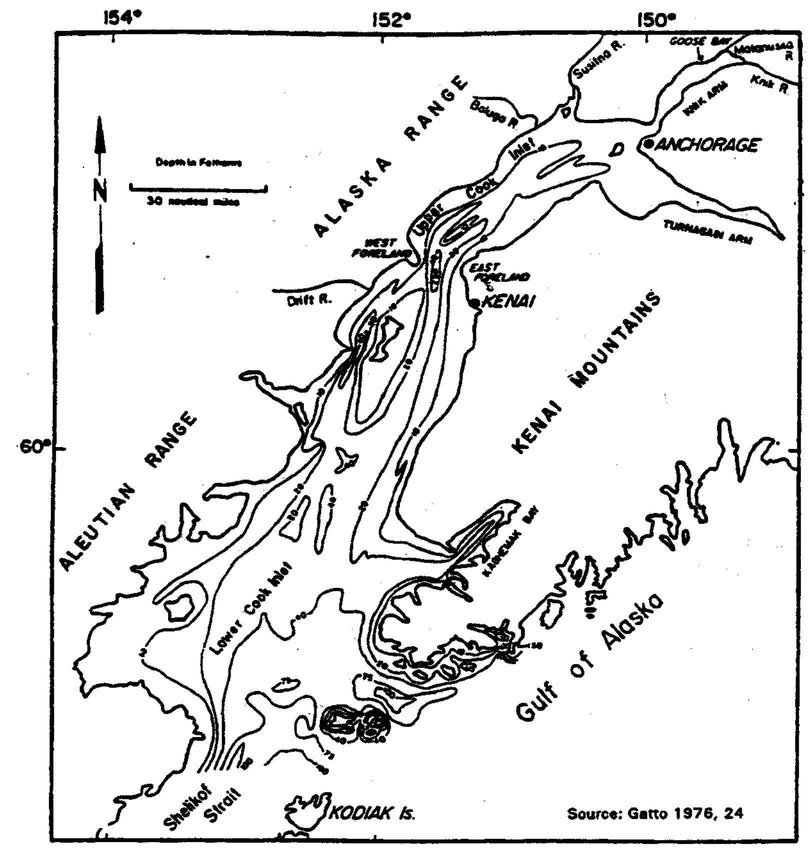


FIGURE 2-3.--Generalized bathymetry of Cook Inlet.

Cook Inlet depths near the Forelands average about 40 m. South of the East and West Forelands, the inlet bottom slopes downward to depths of more than 180 m just outside the inlet mouth at the Barren Islands. Bottom topography is rugged in the lower inlet; many deep areas are interspersed with sandy shoals and rocky pinnacles. Average depth in the lower Cook Inlet is 90 m.

Upper Cook Inlet has the second highest tides in all of the Americas, exceeded only at the Bay of Fundy in Nova Scotia. Mean daily tide range varies from 4.2 m at the mouth of the inlet to 9.0 m at Anchorage. The tides in the inlet occur as two unequal high tides and two unequal low tides per tidal day. A tidal (lunar) day is 24 hours and 50 minutes. The greatest tides occur in the spring, with high and low tides exceeding the mean by more than 1.5 m. Tides vary within the lower portion of the inlet from 5.8 m on the east side to 5.1 m on the west side. The high tide range creates especially strong currents along the eastern shore of the lower inlet. High tide at the mouth of the inlet occurs approximately 4-1/2 hours before high tide at Anchorage (Gatto 1976). Tables 2-2 and 2-3 list tidal ranges and current ranges, respectively, for locations in the southeast, southwest, mid-east, mid-west, and north parts of the inlet.

TABLE 2-2.--*Tidal ranges for various locations within Cook Inlet*

		Tidal ranges	
Site	**Location within inlet**	**Mean[a] (m)**	**Diurnal[b] (m)**
Port Graham	Southeast	4.4	5.2
Kamishak Bay	Southwest	3.9	4.6
Kenai	Mid-east	5.3	6.0
Drift River Terminal	Mid-west	4.7	5.5
Anchorage (Knik Arm)	North	7.9	8.9

[a] Mean tidal range is the difference in height between mean high water and mean low water.
[b] Diurnal tidal range is the difference between mean higher high water and mean lower low water.

Source: NOAA 1994b (*1995 Tide Tables*).

TABLE 2-3.--*Current ranges for various locations within Cook Inlet*

		Current ranges	
Site	**Location within inlet**	**Maximum flood current (knots)**	**Maximum ebb current (knots)**
Cape Elizabeth	Southeast	2.2	1.8
Cape Douglas	Southwest	0.7	1.5
Kenai	Mid-east	2.4	2.6
Drift River Terminal	Mid-west	1.9	3.1
Anchorage	North	3.5	3.1

Source: NOAA 1994a (*1995 Tidal Current Tables*). Refers to depth-averaged currents.

Tidal currents in lower Cook Inlet are classified as rotary currents, since the flow typically does not slow to zero velocity, but rather changes direction through all points of the compass. The upper inlet experiences strong turbulence and vertical mixing during each tidal cycle, so water properties tend to be uniform from the surface to the bottom. The lower inlet tends to be more stratified in temperature and salinity. Currents in the upper inlet are classified as reversing currents, as the flow changes to the opposite direction and is briefly near zero velocity at each high and low tide. Extreme tides can cause currents in upper Cook Inlet to exceed 4 knots in some areas.

Tidal currents are superimposed on the longer-term net circulation trends. Water in lower Cook Inlet generally circulates in a counterclockwise pattern. Less turbid, more saline Gulf of Alaska water enters at the southeast end of the inlet, and sediment-laden fresher water flows out along the west side. Figure 2-4 shows the general circulation pattern of water within Cook Inlet.

The upper inlet's shallow depths usually restrict wave heights to 3 m or less. Waves near Beluga can reach 5 m in height, while waves of greater than 6 m can occur south of Kachemak Bay. Knik Arm waves are further constrained east of Fire Island by limited fetch. Strong tidal currents in Cook Inlet can oppose wind-generated waves, making the waves steeper and more chaotic, a dangerous condition for small boats.

Cook Inlet ice forms in four different ways. The most common type of ice in the inlet is sea ice.. Sea ice forms in seawater as a thin layer, which increases in thickness as layers are added to the bottom. Sea ice can exist in the inlet as floes greater than 300 m wide and up to 1 m thick. Pressure ridges up to 5 m sometimes form as these floes collide (Gatto 1976). Beach ice also forms in the inlet. Beach ice quickly forms on tidal flats as the seawater contacts the frozen tidal mud. Beach ice rarely gets thicker than 1/2 m before floating free of the mud. This floating beach ice often deposits in layers on the mudflats during high tides. These deposits often turn into *stamukhi*, the third type of Cook Inlet ice. Stamukhi is created when overhanging pieces of deposited beach ice break off as the tides recede, leaving behind layered ice with nearly straight sides. These forms occasionally break free during high tides and are carried into the inlet. Beach ice and stamukhi are the last forms of ice to melt in the spring. The final type of ice found in Cook Inlet is estuary or river ice. This type of freshwater ice, similar to sea ice but much harder, is often discharged into the inlet during the spring breakup (LaBelle *et al.* 1983).

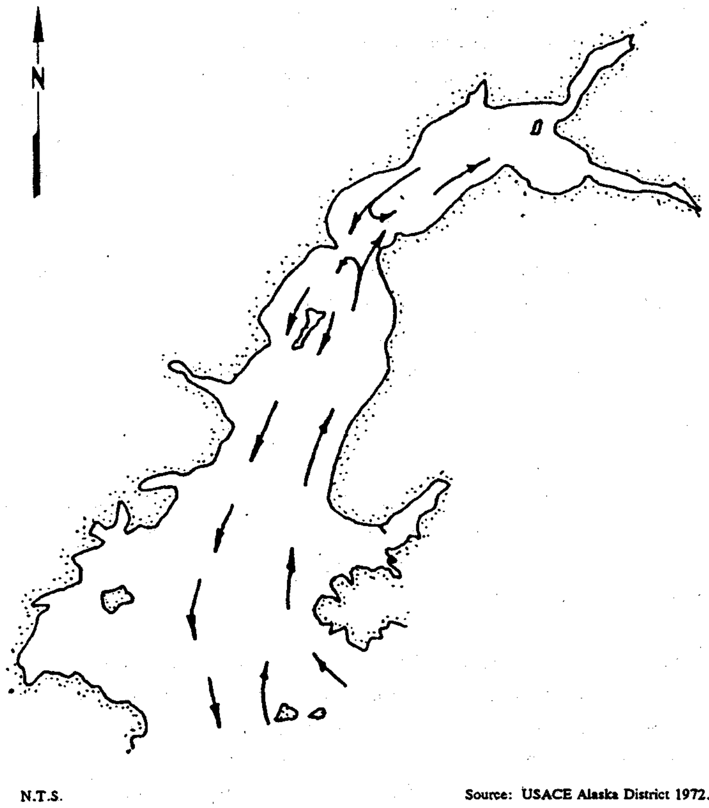


FIGURE 2-4.--Surface circulation pattern, Cook Inlet.

Ice can be a navigational hazard, particularly in the upper inlet, for as long as 5 months of the year. The ice that forms in the less saline waters of the upper inlet is harder than the ice in the lower portions of the inlet. As a result, upper-inlet ice is more dangerous to ships and fixed structures (WAPORA, Inc. 1981). Cook Inlet ice typically first forms in October, but does not cover a significant area of the inlet until late November. By December, ice north of the Forelands typically covers about half of the water surface, but the southern portion of the inlet is generally open water. Cook Inlet often warms in late December and early January, with little to no increase in ice coverage or thickness during this warming period. By the end of January, ice thicknesses in the inlet range from less than 0.5 m to more than 2 m. (LaBelle *et al.* 1983). During a severe winter, continuous pack ice may extend as far south as Anchor Point on the east and Cape Douglas on the west (WAPORA, Inc. 1979). In late March or early April, the only ice remaining in the inlet is the large chunks of beach ice and stamukhi. On rare occasions ice persists until May (Gatto 1976).

2.4.2 Oceanographic Measurements in Knik Arm.

A series of oceanographic measurements were made in Knik Arm as a part of this project, first in June 1992 during the reconnaissance phase, and in May, July, early October, and late November during this feasibility study. Measurements included profiles of temperature and salinity (CTD), water samples that were tested for suspended sediment concentration and grain size distribution, and currents measured by acoustic Doppler current profiler (ADCP). These measurements reveal some seasonal variation of conditions, but strong tidal currents dominate the oceanography in Knik Arm in all seasons.

Turbulence associated with the strong tidal currents in Knik Arm causes the water to be well mixed. Some slight salinity stratification was detected in May; otherwise temperature, salinity, and density were uniform from the surface to the bottom. Water temperatures were 4 to 5 °C in May, 11 to 12 °C in July, and 6 to 7 °C in October. The conditions of the late November excursion were extremely cold, with air temperatures as cold as -7 °C (20 °F) and extensive thickening ice across Knik Arm. The water temperature in these conditions was measured to be a uniform -1 °C.

Salinities were measured to be about 6 to 11 parts per thousand (ppt) at the surface and 12 ppt near the bottom in May, a uniform 9 ppt in July, 8 ppt in early October, and 9 ppt in late November. Lower surface salinities in May are due to spring snowmelt from the rivers, with saltier water from the main inlet beneath. A slightly lower salinity in early October is due to the increase in rainfall that is typical for the region in August and September.

Currents measured in Knik Arm were complex in every dimension. Figure 2-5 shows results from one transect across Knik Arm at Knik Arm Shoal during an ebb tide on October 5, 1994. Each vertical strip in the figure is an individual profile measured by the ADCP looking down from a boat passing from south to north (left to right in the figure) across the crest of Knik Arm Shoal. Woronzof Shoal is on the left and the crest of Knik Arm Shoal is about 2,100 m from the start of the transect. The vertical divisions or "bins" are each 1 m deep. The actual seabed is 1 m beneath the last bin shown in the figure, since unavoidable acoustic effects prevent reliable measurements in the meter just above the bottom. Currents near the surface exceed 2.25 m/sec (4.4 knots) in the channel between Woronzof and Knik Arm Shoals, but reduce to less than 1.35 m/sec (2.6 knots) at mid-depth and less than 1 m/sec (1.9 knots) near the bottom.

Corresponding depth-averaged current direction and speed are shown in figure 2-6. Current direction is uniformly toward the southwest along the natural channel alignment. Current speed generally increases as a function of depth, which demonstrates the strong influence of bottom friction on these fast tidal currents. Additional current measurements are described in appendix A (part 1) of this report.

2.5 Environmental Setting

The natural environment of upper Cook Inlet is discussed in the environmental assessment. The following paragraphs provide only a brief introduction.

2.5.1 Vegetation.

The upper Cook Inlet tidal flats, which extend toward the inlet from about the mean high tide line, consist of exposed mudflats vegetated only by algae. Above the tide line, the vegetation is dominated by grasses interspersed with patches of mud colonized by glasswort. The marshes contain a diverse mixture of wetland, wet meadow, and grass-forb communities. Interior spruce-birch forests dominate the lower slopes and stream valleys.

2.5.2 Animal Life.

Marine Invertebrates. The relatively low diversity and abundance of zooplankton (except copepods) suggest that debris, silt, and low salinity at certain times of the year severely restrict their survival.

Subtidal benthic organisms are sparse in upper Cook Inlet. Burial of organisms by silt, subtidal erosion and scouring of the seafloor by sediment and ice, exceptionally high turbidity, rapid currents, low temperatures, and low and fluctuating salinity all combine to create an unusually

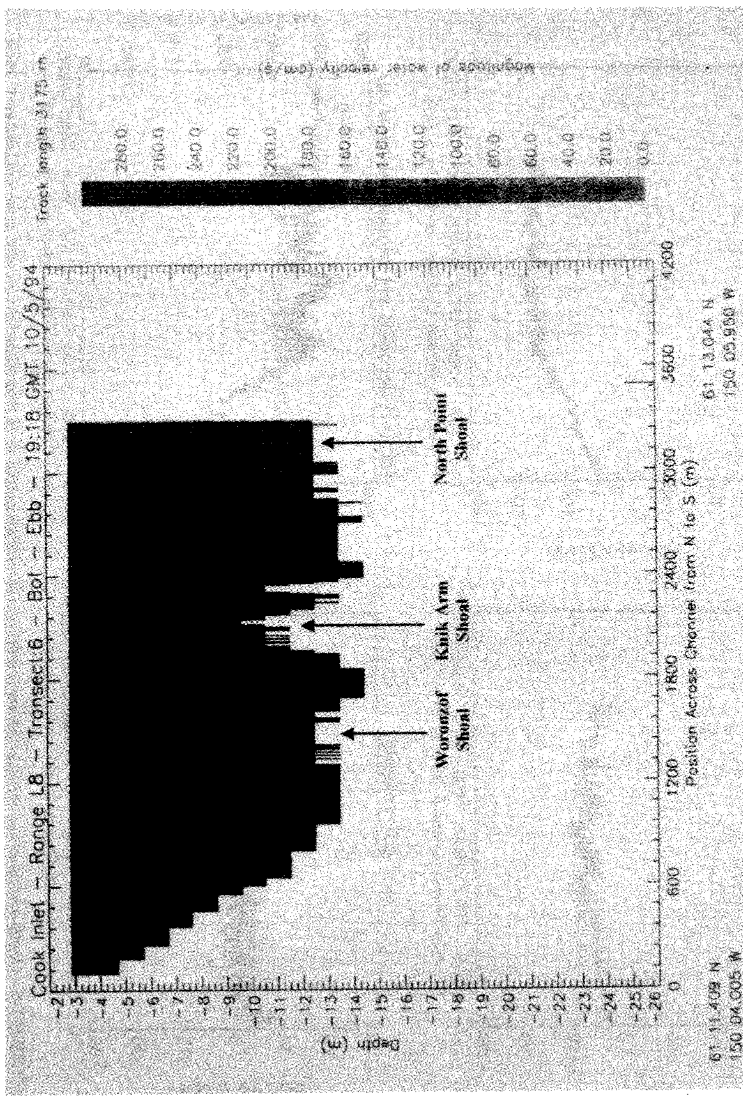


FIGURE 2-5.--Profiles of water speeds across Knik Arm Shoal during ebb flow on October 5, 1994.

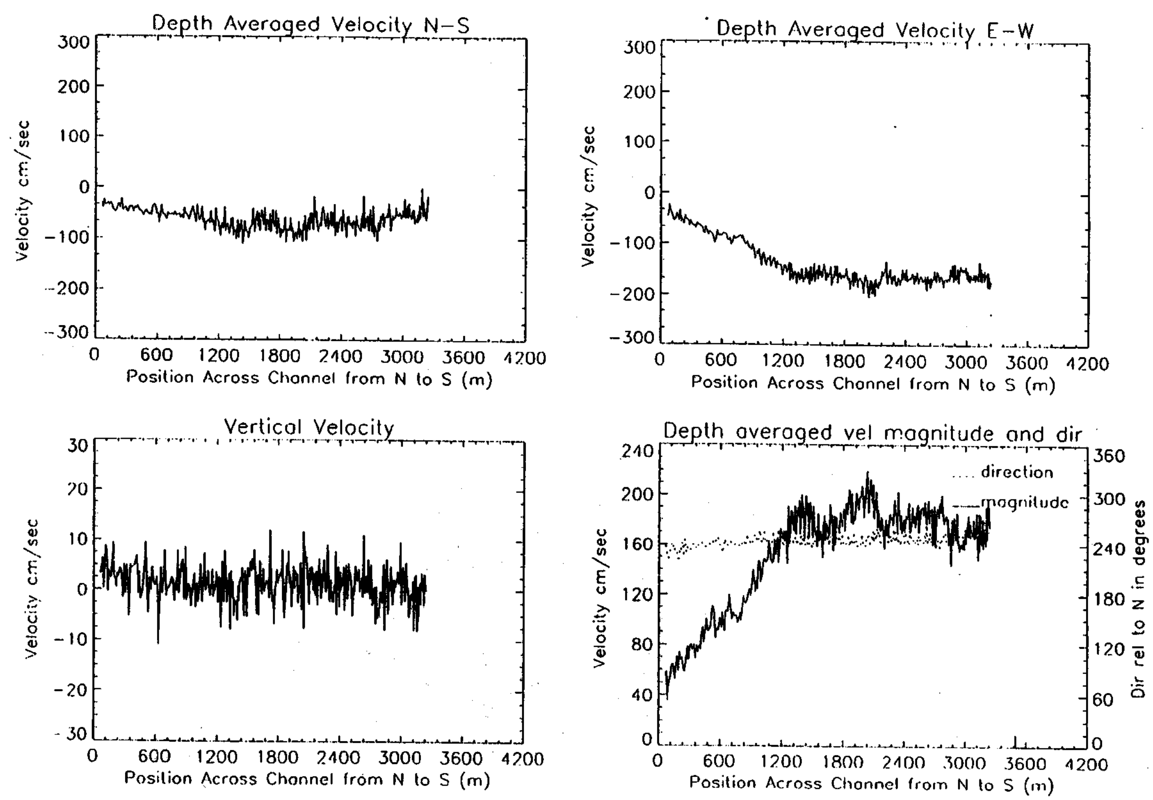


FIGURE 2-6.--Depth-averaged current speed components and directions across Knik Arm Shoal during ebb flow on October 5, 1994.

Fish. All five species of Pacific salmon occur in the waters of upper Cook Inlet, as well as Dolly Varden and eulachon ("hooligan"). These anadromous fish are usually taken from local creeks and rivers rather than in Knik and Turnagain Arms, except for eulachon, which are dipnetted from tidal channels in Turnagain Arm. Data collected since 1954 reveal that recent returns of salmon to upper Cook Inlet are at record or near-record levels. Only set gill-netting is allowed in the Northern District of upper Cook Inlet.

Energy for the moderate production of fish and epibenthic invertebrates occurring in Knik Arm is probably provided by organic detritus from adjacent marshes and streams.

Birds. The commonest waterfowl using northern Cook Inlet salt marshes and wetlands are pintails, mallards, green-winged teal, and lesser Canada geese. Among the commonest shorebirds are plovers, sandpipers, yellowlegs, dowitchers, and phalaropes. Highest population levels occur during spring, when the marshes are used heavily by lesser Canada and snow geese, ducks, and occasional swans and cranes. As many as 100,000 waterfowl use the Susitna Flats salt marsh in early May to feed, rest, and conduct their final courtship prior to nesting. The limiting factor for birds in the Point Woronzof/Knik Arm area may be food. Shorebirds were found in greatest numbers where there were clams and gammarid amphipods, as well as a rich algal cover.

Marine Mammals. Although 23 species of marine mammals are present in Southcentral Alaskan waters, only a few reach the upper Cook Inlet north of the Forelands. Cook Inlet supports an apparently distinct population of 300 to 400 beluga whales during the summer. The availability of adult salmon and smolt and eulachon apparently accounts for their presence in the area. Harbor seals inhabit Augustine and Shaw Islands and occur on the entire west side of Cook Inlet, with a concentration at the mouth of the Susitna River (Evans *et al.* 1972). Killer whales have been observed in the upper inlet, and minke whales and harbor porpoise have been seen in Turnagain Arm and at the mouths of rivers chasing eulachon. Sea lions have been observed but are rare.

3. HUMAN HISTORY, DEMOGRAPHY, AND GOVERNMENT

3.1 Indigenous People

Both historical and archeological data show that Alaska populations have tended to migrate to the Southcentral region of Alaska, specifically around Kodiak Island, Cook Inlet, and Prince William Sound. The upper Cook Inlet area has been inhabited possibly for as long as 9,000 to 10,000 years. Few archeological sites of this age are known for this area, with the possible exception of Beluga Point, south of Anchorage on Turnagain Arm (Reger 1981). A date of 9,000 years ago is indicated by artifacts found in the lowest level of the Beluga Point site. A more recent component of Beluga Point dates to between 3,000 and 4,000 years ago and shows affinities to the Alaska Peninsula Arctic Small Tool tradition. A slightly later component from a different area of the site resembles a Bering Sea variant of the Norton tradition, which is typified by a greater variety of tools and larger settlements. This component is thought to date to between 2,200 and 2,500 years ago. Two more recent levels are thought to be related to the Kachemak area, dating to about 1,000 years ago. This relatively elaborate culture is also found at the Fish Creek site on the northern shore of Knik Arm. More recent Thule artifacts, such as Thule pottery, are also known in the Cook Inlet area (Dumond 1977).

At the time of the first European contact in the 18th century, the Tanaina Indians inhabited the Cook Inlet region and the Chugachmiut Eskimos lived in northwestern Prince William Sound. The Yukon Island archeological site in Kachemak Bay shows that this area of lower Cook Inlet was occupied by Eskimos from about 1500 B.C. to A.D. 1000, and then by Athapaskan Indians, probably the ancestors of the Tanaina, who moved into the coastal area from the Interior. However, other archeological sites such as Fischer-Hong and Fish Creek indicate there was an Eskimo population in Cook Inlet as recently as 300 years ago and that the Tanaina initially moved into the area from the Copper River between 1650 and 1780 A.D. (Dumond and Mace 1968). Several Tanaina villages were in the Fort Richardson area (just east of Anchorage), the two prominent settlements being Eklutna and Knik. Summer fish camps are known to have existed at the mouth of Ship Creek, Point Woronzof, Fire Island, and the mouth of Eagle River near Anchorage (Steele 1980).

3.2 European Exploration

3.2.1 Russian.

Vitus Bering's discovery of Alaska in 1741 triggered the great wave of European exploration of Alaska. By 1790, Russian settlements were scattered from the Aleutian Islands and the Pribilofs to the islands of Southeast Alaska. The first permanent Russian settlement in Southcentral Alaska was founded in 1784 at Three Saints Bay on Kodiak Island. By 1792, permanent Russian settlements had been established along the Kenai Peninsula, from which an active trading operation was carried into Prince William Sound.

3.2.2 English.

Captain James Cook, one of England's greatest navigators, sailed for Alaska in 1776 on a 3-year journey looking for a northern passage from the Pacific to the Atlantic. With two ships, the *Resolution* and the *Discovery*, Cook's expedition sailed north from Nootka Sound, near Vancouver Island, on April 26, 1778. The expedition reached Prince William Sound around the middle of May. After failing to find the passage they were searching for, the two ships turned southward. On May 21, the southeastern point of Cook Inlet was sighted and named Cape Elizabeth. Russian maps of the time depicted Alaska as an island. Cook, believing Kodiak and Afognak Islands, with Cape Douglas in the foreground, formed part of a mountainous coastline to the west, entered the inlet thinking it was a passage to the Arctic Ocean between the island and the North American continent.

Although he later realized this was not the passage he sought, Cook continued to sail up the inlet, which he thought of as the "Great River" because of the muddy water and floating trees he encountered on the voyage (Bancroft 1886). He anchored his ships southeast of Fire Island. On June 1, the small boats that had been sent out to explore the area returned after discovering the inlet split into two arms, Turnagain and Knik. Sailing south, the ships left Cook Inlet on June 5 and headed southwest along the Alaska Peninsula coastline in search of an opening to the west and north.. Cook's mapping of the Alaska coast became the standard guide for more than a century. He also first proved that America and Asia were not joined.

3.2.3 Spanish.

Russian activity in the north did not go unnoticed by the Spanish. Fear of Russian expansion to the south resulted in increased activity by the Spanish in the Pacific. The viceroy of Mexico sent several expeditions north--in 1774, 1777, 1778, and 1790--to take possession of Alaska for Spain. In 1779 a Spanish expedition entered Prince William Sound and claimed it for Spain, the third nation to lay claim to the sound in 2 years. The Russians had claimed it earlier the same year, while Cook, representing England, had done so in 1778. Other than a few place names, such as Valdez and Cordova, Spain left no trace of its northern exploration. Spanish explorers are not known to have reached Cook Inlet during this era.

3.3 American Rule

The United States bought Alaska from Russia in 1867 for $7.2 million. However, it wasn't until 1912 that Alaska was granted true territorial status with its own legislature. Congress passed the Alaska Statehood Bill on June 30, 1958, and on January 3, 1959, Alaska became the 49th State. Coal, gold, fishing, and railroad construction played large roles in the development of the Southcentral region. The start of the commercial fishing industry in Southcentral Alaska can be traced to Karluk on Kodiak Island, where the first fish cannery in the region was established in 1882. During the next 20 years, canneries were established throughout the region. Cook Inlet and Prince William Sound remain important to Alaska's commercial fishing industry.

The Yukon gold rush of 1897 largely bypassed Southcentral Alaska. However, the discovery of gold in Fairbanks in the early 1900's led to the establishment of railroads from Prince William Sound and Cook Inlet to the Interior. Businesses soon sprang up to haul freight from Valdez to Fairbanks over the Richardson Trail.

Immigration into the region from Europe and the United States increased rapidly during the first decade of the 20th century. The construction of a railroad between Cordova and Chitina in 1908 established Cordova as one of Alaska's leading ports, while Valdez maintained its importance as the port of entry to the Richardson Trail.

3.4 Anchorage

Alaska's largest city was founded as a railroad construction camp at the mouth of Ship Creek in 1915 by the Alaska Engineering Commission (AEC). The commission was mapping a railroad expansion route to connect Seward with the Interior coal fields (Hill 1992). The AEC found the Ship Creek location desirable because of the convenience it afforded in launching railroad construction to the Matanuska coal fields. Although closer to Seward than to Fairbanks, the site served as a "midpoint" between the two. A tent city of approximately 2,000 people immediately sprang up on the north side of Ship Creek underneath the plateau of what is now called Government Hill. In July of that year 655 town lots were auctioned off, and development of a permanent city began.

Originally called Ship Creek, the town later was referred to as Anchorage because of the ships that used to "lie at anchorage" in Knik Arm to allow supplies to be taken ashore. The U.S. Post Office officially gave the town its name when the newly appointed postmaster insisted mail be sent to "Anchorage." Although the AEC protested, its preference for the name Ship Creek was passed over as maps and news accounts quickly adopted the name "Anchorage." In August 1915 voters chose the name Alaska City, but petitions to the Federal Government to change the name were to no avail (Carberry 1979).

On January 1, 1917, the railroad's headquarters were transferred from Seward to the Ship Creek townsite. Anchorage officially incorporated on November 23, 1920, ending the Federal role in operating the Anchorage townsite. The railroad was completed in 1923.

Population growth in Southcentral Alaska was slow from the 1920's until World War II. In 1939, Anchorage's population was slightly more than 4,000, third in size after Juneau and Ketchikan. In less than a decade, though, its population grew to 40,000, and Anchorage became Alaska's largest city.

Several decisions made by the Federal Government in the 1930's significantly affected Anchorage's development as Alaska's major city. The Civil Aeronautics Board realized that Anchorage's location was ideal for air transport and radio communication. The Army Corps of Engineers, in cooperation with the Alaska Railroad, mapped a 12.5-mile rail route from Portage, 47 miles south of Anchorage, to the deep-water port of Whittier, bypassing Seward. The Federal Government also expanded its role in Anchorage under New Deal programs by establishing agency headquarters there and by switching the District Court from Valdez to Anchorage (Carberry 1979).

The establishment of military bases in Anchorage in 1940 brought the first significant wave of people since the building of the railroad. Smaller communities in the region lost population as people moved into Anchorage in search of jobs. Alaska was envisioned as a vital link in the Nation's air defense system, and Elmendorf Field (now Elmendorf Air Force Base) was a major part of that system.

The next influx of people into the Anchorage area after the war came with the building of the DEW (Distance Early Warning) line radar installations from 1949 to 1958 (University of Alaska 1974). Although the actual sites were constructed all over Alaska, Anchorage was the administrative, financial, and logistics center for the project. By 1954 Anchorage was the Nation's fourth busiest air traffic operations center, earning the nickname "Crossroads of the Air World." The city's role as the State's transportation, communication, service, and financial center was becoming well established (Hill 1992).

The discovery of oil on the Kenai Peninsula in 1957, in Cook Inlet in 1966, and at Prudhoe Bay in 1968 further contributed to Anchorage's emergence as the State's economic center. Major oil corporations and support services located their headquarters there. National companies and State and Federal agencies also established offices in Anchorage.

The recent decline in the oil industry has not affected Anchorage's status as Alaska's center of commerce. The Port of Anchorage serves about 85 percent of Alaska's population and is the primary link between Outside suppliers and Alaska industry and consumers. Anchorage International Airport is one of the busiest cargo airports in the Nation. Equidistant from Asia, Europe, and North America, the airport services approximately 70 percent of all cargo between Pacific Asia and Europe and 95 percent of all air cargo between North America and Pacific Asia (Hill 1992).

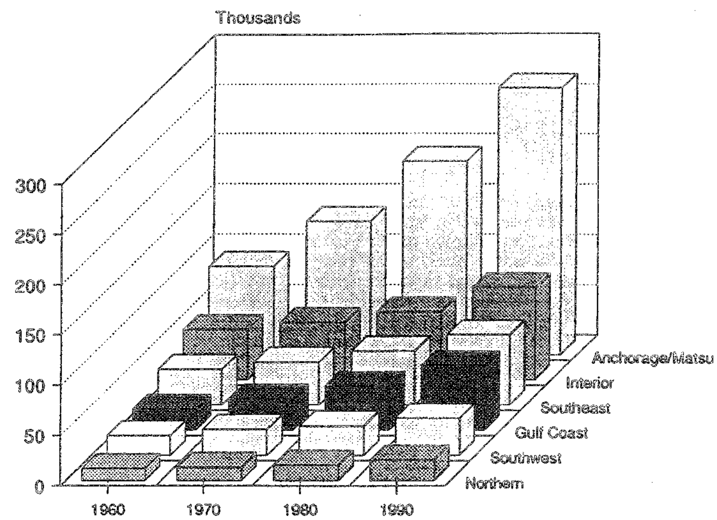
3.5 Demography of Southcentral Alaska

More than 60 percent of Alaska's population resides in Southcentral Alaska. From July 1960 to April 1990, Anchorage's population increased by 143,505 (a 173.2-percent increase), the Matanuska-Susitna Borough's by 34,495 (a 665.9-percent increase), and the Kenai Peninsula Borough's by 31,749 (a 350.7-percent increase). These boroughs represent three of the five fastest-growing areas in Alaska. The Matanuska-Susitna Borough was the fastest-growing area during the 1980's, increasing by 112.7 percent, from 17,816 in 1980 to 39,683 in 1990. Table 3-1 shows the population from 1960 to 1990 by borough and census area.

According to the 1990 census, the Municipality of Anchorage has a population of 226,338, or 41 percent of the State's population. The Kenai Peninsula Borough has the second largest population in the Southcentral region with 40,802, followed by the Matanuska-Susitna Borough with 39,683 and the Valdez-Cordova census area with 9,952. Figure 3-1 shows the population in Alaska by labor market region from 1960 to 1990.

TABLE 3-1.—*Borough and census area population, 1960-1990*

	1960	1970	1980	1990
Anchorage	82,833	126,835	164,431	226,338
Matanuska-Susitna	5,188	6,509	17,816	39,683
Kenai Peninsula	9,053	16,856	25,282	40,802
Valdez-Cordova	4,603	4,977	8,348	9,952



Source: Alaska Department of Labor, Research & Analysis, Demographics Unit.

FIGURE 3-1.--Alaska population by labor market region, 1960-90.

More Alaska Natives now live in Anchorage (14,569) than in any other borough or census area in the State. The greatest increase occurred in the Anchorage/Matanuska-Susitna region, which had 15 percent of the Alaska Natives in 1980 and 19.3 percent in 1990.
The population in Alaska is younger than the national average. The median age in the United States in 1989 was 31.5 for males and 33.8 for females. In Alaska, the 1990 median age was 28.5 for males and 28.4 for females.

Armed Forces personnel in Alaska have played a significant role in the State's population growth. Currently, the military population, including family members, accounts for 10 percent of the State's population.

4. PORT FACILITIES AND WATERBORNE COMMERCE

4.1 Port Facilities

4.1.1 History.

Dock facilities have been located at the mouth of Ship Creek since 1915, when a dock was constructed on the north bank of Ship Creek near the mouth. A grid was built in front of the dock; barges were floated over the grid during high tide and rested on it during low tide. A 15-ton derrick was available for unloading the barges (Carberry 1979).

Construction on the Ocean Dock, at the present site of the Port of Anchorage on Knik Arm north of Ship Creek, began in the summer of 1918. With its opening in September 1919, the earlier dock at the mouth of Ship Creek took on a secondary role. The S.S. *Anyox* was the first oceangoing vessel to use the Ocean Dock. Because steamships could dock at Anchorage, they were able to avoid the high railroad rates between Seward and Anchorage. The railroad estimated it lost $28,000 per year to the steamships that used the port facility. The railroad management believed that closing the port would mean new revenue for the railroad. To avoid a confrontation with the steamship companies, new rates were negotiated to ease the cost of the Seward-Anchorage haul. The railroad manager, Noel Smith, closed the Ocean Dock in the fall of 1924. The dock was minimally maintained and used only in emergencies or to export large shipments of minerals. Heavy use of the dock did not occur again until World War II (Carberry 1979).

Once the Ocean Dock was closed, a new dock was needed to accommodate the smaller boats serving the inlet's communities. The Anchorage City Council and the railroad agreed to share the costs of building a new dock. The railroad completed the project in 1927; however, the city council did not approve of its construction and refused to pay its share. This facility was originally called the City Dock; later it also was known as the ARR (Alaska Railroad) dock.

Congress authorized the Corps of Engineers in 1947 to investigate the feasibility of building a port on Fire Island with a causeway to Anchorage. A study of navigation needs for the entire inlet was completed in 1950, which recommended improvement of the City Dock and dredging an approach to the dock at 10.7 m (35 feet) below Mean Lower Low Water (MLLW). Two rock jetties were also proposed to protect the port and dredged area. The Board of Engineers in Washington, D.C., approved the project without the jetties in 1953. During this time the Anchorage Port Commission independently conducted studies of port improvements with conclusions similar to those of the Corps study.

The Corps originally pursued the purchase of a dredge to improve depths at the City Dock, but did not receive funding for any construction work until after the 1964 earthquake. The city of Anchorage sold bonds to fund improvements to the dock, which were completed in 1961. The earthquake completely destroyed the City Dock in March 1964. The city built a petroleum pier in 1964 with Federal funds, but the hastily constructed pier was destroyed by ice the following winter. The city sold new bonds in 1965 to rebuild the City Dock, and the Corps began a program of maintenance dredging that year, using contracted dredging equipment. The approaches to the dock and its later expansions have been surveyed and dredged annually by Corps contractors ever since (Jacobs and Woodman 1976).

4.1.2 Facilities at Port of Anchorage.

The facilities of the Port of Anchorage (figures 4-1 and 4-2) are owned by the Municipality of Anchorage, and the Port of Anchorage administration is an agency of that government. Berths at the port include two liquid bulk terminals, both essentially dedicated to import petroleum, oil, and lubricants (POL). Liquid bulk storage and transfer facilities surround the port area; these facilities are owned and operated by several commercial enterprises and one military unit. The first petroleum terminal, POL 1, is an offshore wharf 187 m long, including dolphins. The dock is used primarily to receive petroleum products and bunker vessels; however, occasionally it is used to receive general cargo shipments. POL 2 is a newer T-head dock just south of the main pier. The terminal is used primarily to unload refined petroleum products. POL 2 is equipped with a hose tower with four 20-cm petroleum hoses supported by tide compensating reels. Each hose has a 318-m^3-per hour pumping rate.

The remaining facilities of the Port of Anchorage consist of three terminals distributed along a 680-m continuous pier, which is oriented north-south (generally parallel to the natural shoreline). The surface of the pier is paved for truck traffic and includes rails for conventional rail car access and rails for positioning level-luffing break-bulk cargo cranes and lift-on/lift-off container cranes. Terminal 1 is the southern 183 m of the pier and is

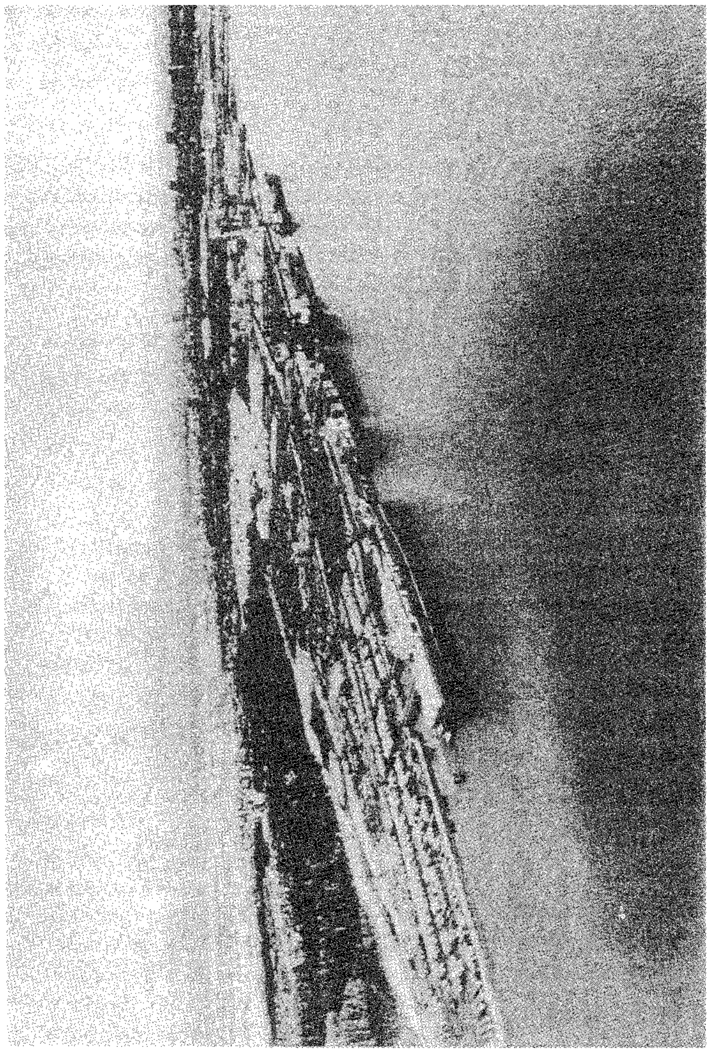


FIGURE 4-1.--Cargo ships at the Port of Anchorage.

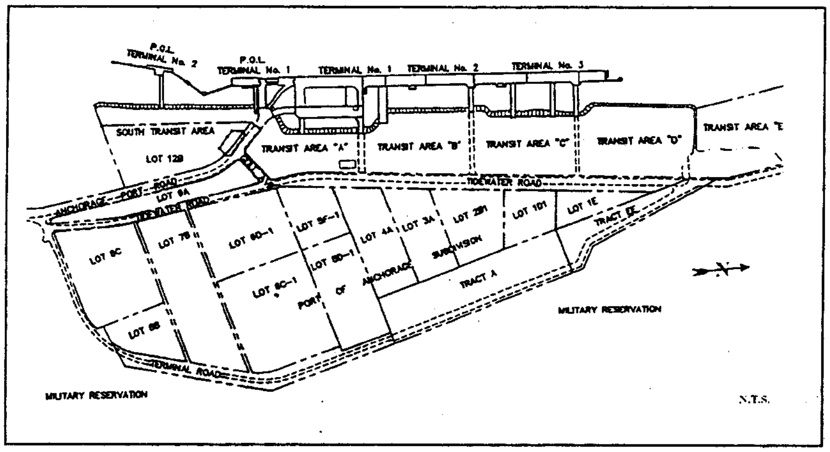


FIGURE 4-2.–Map of Port of Anchorage.

used to transfer break-bulk cargo with level-luffing cranes on rails. Terminal 1 also has the capability for container lift-on/lift-off and trailer roll-on/roll-off (RO/RO) cargo operations. The adjacent 186-m-long Terminal 2 is used primarily for container lift-on/lift-off operations and is available on a preferential basis to Sea-Land Service, Inc. It also has the capability to handle RO/RO and break-bulk cargo. A 2,500-m^2 heated transient warehouse is located on the pier adjacent to terminals 1 and 2.

Terminal 3 is 308 m long, including its single mooring dolphin. It is primarily used for RO/RO operations of Totem Ocean Trailer Express, Inc. (TOTE). It has special rolling ramps that can be adjusted for changes in tide to meet openings on the port sides of the three TOTE ships serving the port. Terminal 3 also has container and break-bulk capabilities.

Cargo handling equipment at the Port of Anchorage includes three level-luffing, rail-mounted, diesel electric gantry cranes, one with a 7.5-ton capacity and two with a 40-ton capacity and 5-ton whips. The port also has two 28-ton, rail-mounted, electric container cranes and a 40-ton, rail-mounted, electric container crane. Portable cranes with 150-ton capacity and 30-ton capacity forklifts are available. The Port of Anchorage has two privately owned, 20-cm-diameter bulk cement lines. Fresh water, telephones, and contracted fuel, sewer, and garbage service are available. More than 15 hectares of public cargo transit area is located next to the wharf in the 44.5-hectare port industrial park. Four gangs of stevedores are available on a 4-hour notice; up to 10 gangs are available with 12 hours' notice.

4.1.3 Other Anchorage Port Facilities.

The Lone Star Cement Anchorage facility is located south of POL 2. Alaska Basic Industries operates the two bulk-cement facilities, which are connected by pipeline to the Port of Anchorage pier for transfer of cement from deep-draft vessels. A grounded 250-foot landing ship at the cement site is used to receive cement by barge.

The Chugach Electric Association Marine Division dock is 30 m south of the Lone Star terminal. Chugach leases the dock from the Alaska Railroad Corporation. Operated by Pickworth and Associates, Inc., the dock provides 88 m of barge berthing space, which goes dry at low tide. Handling equipment includes cranes with capacities up to 53 tons and three forklifts. Two hectares of open storage is available.

The North Star Terminal and Stevedore Company owns and operates the Anderson dock facility 366 m south of the Chugach Electric dock. The dock has a 107-m face and goes dry at low tide. It is used to receive and ship general cargo, containers, and heavy lift equipment by barge. The berth is regularly dredged by dozers at low tide. The railroad spur to the dock is used to load shipments to and from rail cars. Cranes with capacities up to 150 tons are available. More than 900 m^2 of covered storage and more than 5 hectares of open storage is available. A permit from the Corps of Engineers will allow North Star to fill out to 0.0 MLLW, which will add more than 3 hectares of upland storage and staging area.

The Minch dock is located just south of the Anderson dock. Owned and operated by Douglas Management, Inc., the 110-m bulkhead, which goes dry at low tide, is used for modular buildings, bulk salt, equipment, and general cargo unloading. Cranes with capacities up to 150 tons and 5 hectares of open storage are available. Douglas Management has a Corps of Engineers permit to extend the filled area to 0.0 MLLW to add more than 1.6 hectares of open storage area.

The Whitney Fidalgo Anchorage dock is on the north side of Ship Creek, 275 m above the mouth. Owned and operated by Kyokuyo USA, Inc., the dock is used to receive fish and seafood. It has 65 m of docking space and goes dry at low tide.

The site of the old small boat facility is 183 m upstream of the Whitney Fidalgo Anchorage dock. It returned to Alaska Railroad Corporation ownership with the construction of a new facility at Ship Creek Point. A 27-m pier and a few tie-up spots used by transient boats still exist.

The Port of Anchorage developed a small boat facility 275 m south of the mouth of Ship Creek between 1986 and 1989. The municipality owns and operates the boat launch, a 15-m interim maritime dock, and a staging area on a 2.2-hectare site leased from the Alaska Railroad.

Knik Dock is located on the west side of Knik Arm, 4 km north of Anchorage. It has a 100-m face and is equipped with a 25-ton crawler crane, a D-8 Caterpillar, a wheel loader with forklifts, a 9-m^3 end dump truck, a 15-ton forklift, a John Deere 450 dozer and a John Deere crawler loader. A tug is on call 24 hours a day. Storage facilities include 10 hectares of private staging area and 335 m^2 of dry heated storage. The dock has water, fuel, and power available.

Development of a deep-draft port in the vicinity of Knik Dock has been under study by the Matanuska-Susitna Borough for more than 10 years at an expense well in excess of $1 million. The proposed port site, called "Port MacKenzie," is approximately 80 km by road from Anchorage via the Glenn and Parks Highways and the unpaved Knik Road. Around 4,000 hectares of land is available for port development. Facilities for export of coal and for imports and exports associated with a proposed iron ore reduction plant have been proposed. A piling-supported pier has been conceived to extend to natural depths of 18 m at MLLW, which would allow service to Panamax-class dry bulk ships. The channel improvements discussed in this report are critical to the operational feasibility of such a facility. Private developers have yet to commit to finance any of the industrial development that would drive completion of new port facilities, but prospects continue to be studied by the borough and private interests.

4.2 Waterborne Commerce

4.2.1 General

The waterborne commerce of Southcentral Alaska is constrained by demand for imports to and exports from the region and by the physical limitations of the port facilities. Port operations are further constrained by limitations of the road and rail links which connect the ports with the hinterland resources or markets. The State-funded "Southcentral Ports Development Project," (Peratrovich, Nottingham and Drage 1993) and the Reconnaissance Report (USACE Alaska District 1993) summarize conditions of Southcentral Alaska roads and railways and the historical throughput of ports in the region. A discussion of Port of Anchorage historical data and trends follows.

4.2.2 Historical Commodity Movements.

Before 1964, freight was moved throughout Southcentral Alaska by train from deep-water ports at Seward and Whittier. Steamship lines brought general cargo to Seward, where it was transferred to rail cars and moved to population centers at Anchorage, Palmer, and Fairbanks. From Seward, this involved a rail movement of about 200 km to Anchorage and 600 km to Fairbanks. The 200-km section between Seward and Anchorage includes some of the steepest grades and most difficult terrain on the Alaska Railroad system. Freight that required specialized handling, such as heavy machinery, pipes, and vehicles, was carried to Whittier by rail barge or train-ship and moved by the Alaska Railroad to major population centers.

Following the Good Friday earthquake of 1964, the Port of Anchorage emerged as the only major operable shipping facility in the region. As a result, major changes took place in waterborne transportation in Alaska and the railbelt area in particular. The outmoded steamship service to Seward was replaced by a modern fleet equipped to deliver containerized cargo to the Port of Anchorage. Freight could then be distributed by rail or truck to local business or to cities in the railbelt area. General cargo tonnage through the Port of Anchorage increased from 398,000 tons in 1970 to 1.2 million tons in 1980.

Table 4-1 shows the amounts of various types of cargo through the Port of Anchorage from 1985 through 1994. From 1991 through 1994, containers and trailer-van traffic averaged 55.7 percent of total throughput, petroleum traffic averaged 40.3 percent, and bulk commodities averaged 3.8 percent.

The decline in petroleum shipments during the early 1980's was due to the completion and use of a pipeline to Anchorage from the refinery at Nikiski on the Kenai Peninsula. Petroleum shipments through the port have increased rapidly in recent years, from about 561,000 tons in 1985 to 1,142,000 tons in 1994. Total cargo increased from 1,925,000 tons in 1985 to nearly 2,700,000 tons in 1994, an increase of about 40 percent, or an annual increase of about 3.8 percent.

TABLE 4-1.--*Historical commodity flow, Port of Anchorage, 1985-94 (tons)*

Commodity	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Iron or steel	23,604	9,026	348	28	121	1	0	3,693	719	21,711
Lumber	1,726	65	0	6,727	2,873	14	25	4,598	5	0
Vehicles	2,664	1,934	1,879	2,037	2,288	2,262	1,467	4,510	216	3,707
Freight, NOS	9,222	1,826	903	891	148	896	327	25,081	23,720	260
Petroleum, NOS	6,272	3,084	271	1,684	1,189	747	2,358	3,677	2,418	4,590
Coal	0	0	0	0	0	0	0	0	0	0
Transshipped cargo	37,786	10,191	14,821	10,933	8,560	0	272	0	0	0
Insulation	0	0	0	0	0	0	0	0	0	0
Cement	87,927	70,149	57,312	48,328	66,103	76,101	63,164	82,727	80,010	97,758
Vans, flats, containers	1,194,846	1,138,143	1,152,611	1,133,461	1,263,008	1,324,262	1,318,940	1,374,285	1,424,894	1,445,769
SUBTOTAL	1,364,047	1,234,418	1,228,145	1,204,089	1,344,290	1,404,283	1,386,553	1,485,770	1,531,042	1,548,377
Petroleum, bulk	561,151	385,995	514,564	701,484	963,570	791,193	925,173	873,232	1,091,479	1,142,066
TOTAL	1,925,198	1,620,413	1,742,709	1,905,573	2,307,860	2,195,476	2,311,726	2,359,002	2,622,521	2,690,443

NOS = Not otherwise specified.

5. PROBLEM IDENTIFICATION

5.1 Approaches to the Port of Anchorage

The findings of the Reconnaissance Report (USACE Alaska District 1993) were confirmed in the feasibility study in that no deep-draft navigation problems of Federal interest were discovered in Cook Inlet except those in Knik Arm along the approaches to the Port of Anchorage. The Port of Anchorage is Alaska's largest containerized and break-bulk cargo port. Anchorage and the areas it directly serves by road, rail, and air include more than 80 percent of Alaska's population. Anchorage is the commercial center of the State, and the municipal port facilities serve as the region's primary maritime link to the Pacific Rim. All deep-draft vessels suffer tidal delays approaching and departing the Port of Anchorage. The maneuvering area at the dock is now authorized for Federal maintenance at -9.75 m MLLW, which requires excavation of an average of 172,000 m^3 of silt each year.

5.1.1 Fire Island Shoal.

Fire Island Shoal lies across shipping routes into the port to the north and west of Fire Island, as shown in figure 2-3 (section 2). This shoal has in prior decades presented an obstacle to deep-draft shipping. The present system of aids to navigation still includes a visual range (Race Point Range) with an alignment south of the present crest of Fire Island Shoal. Deep-draft vessels discontinued use of this range on approach to Anchorage about 10 years ago. The crest of Fire Island Shoal was found at that time to have migrated southward so much that the Race Point Range no longer provided a practical route into Knik Arm. Deep-draft ships now pass north of the crest of Fire Island Shoal and eastward along the Point Woronzof Range, over controlling depths of about 14.6 m at MLLW across about 3.6 km width. Fire Island Shoal therefore is not a significant hindrance to deep-draft vessels at present, but its migratory history could cause the shoal to cause problems again in future decades.

5.1.2 Knik Arm Shoal.

The current system of aids to navigation guides ships south of the shoal on approach to Anchorage along the Point Woronzof Range, past green buoy "7" at the south side of the Knik Arm Shoal crest. Vessels departing Anchorage are directed along the Point MacKenzie Range north of Knik Arm Shoal past buoy "2KA" at the north side of the shoal crest. NOAA hydrographic surveys in 1992 and 1994 indicate that Knik Arm Shoal has been encroached by North Point Shoal on its north side, such that deep-draft traffic now passes only to the south of the two merged shoals. Controlling depths to the north of the crest of Knik Arm Shoal are about -7.5 m at MLLW and to the south about -8.5 m at MLLW. These depths constrain 10-m-draft ships to cross the shoal during the upper half of the tide cycle.

A Federal interest in navigation improvements at Knik Arm Shoal exists and has been the subject of previous studies. These studies, prior to the reconnaissance phase of this study, found no economically feasible alternatives. More recent changes in shipping practices and port-related costs have warranted further investigation of the feasibility of excavated channel improvements. The port expanded its liquid-bulk hauling facilities in 1991 and has enhanced its break-bulk and container handling capabilities in a steady sequence of dock, cargo handling, and upland storage and staging improvements. The two competing freight liner services calling on Anchorage, Sea-Land Services, Inc., and Totem Ocean Trailer Express (TOTE), have improved their vessels to be unusually fast (more than 20 knots) in transits from Tacoma to Anchorage. TOTE added a third roll-on, roll-off vessel for its growing Anchorage trade in 1993. Delays and other expenses stemming from the presence of Knik Arm Shoal along the shipping route cause increased transportation costs to these and other deep-draft ships delivering bulk materials to the port.

5.2 Area Port Improvements Contemplated

5.2.1 Fire Island Port.

The feasibility of a new port facility on Fire Island was investigated by the State of Alaska in 1992 but was found to be too expensive for immediate State investment. A principal incentive for this development was to avoid the delays caused by Knik Arm Shoal, which lies between Fire Island and the Port of Anchorage. Another incentive was to allow deeper-draft ships to serve Anchorage without increasing the annual maintenance dredging expense at the existing Port of Anchorage. It now appears no port development will occur on Fire Island in the foreseeable future, and thus no associated Federal interest exists.

5.2.2 Port MacKenzie.

Coal deposits in the Matanuska River valley within the Matanuska-Susitna Borough have been proposed for export from a new port on Knik Arm. The borough has been planning a port development since 1981 known as Port MacKenzie, to be located on the west side of Knik Arm north of Point MacKenzie. This facility has been proposed in several forms. One proposal included a tideland fill for export of timber products from the borough. The second phase of this proposal included a coal trestle extending to natural depths of 18 m at low tide. This facility is envisioned as requiring no routine maintenance dredging, either at the dock or in the adjacent maneuvering area. The Panamax-class coal carriers that would call at Port MacKenzie would benefit significantly from any channel improvements across Fire Island or Knik Arm Shoal, however. Coal prices and unsettled political issues related to the status of the lands on which the coal exists have diminished interest in coal exports from a new Port MacKenzie.

Midrex, Inc., an American subsidiary of the Japanese Kobe Steel Company, proposed in 1993 to build an iron-ore reduction plant at the site proposed for Port MacKenzie. Affordable natural gas, available real estate, and stable government were among the advantages of the site for placement of the plant. The industrial process involves reduction transformation of iron ore pellets to briquets of pure iron. Iron ore would be imported on Panamax-size or larger ships, and iron briquets would be exported on the same or similar ships. Disadvantages of the site included severe winter weather ashore, winter ice in the inlet, and the presence of Fire Island and Knik Arm Shoals along the shipping route to the proposed port. These disadvantages ultimately led Midrex and Kobe Steel to withdraw from the proposition. Other steel companies have expressed interest in the site, but at present there are no imminent plans to develop Port MacKenzie for deep-draft vessels.

5.2.3 Improvements to Port of Anchorage.

The Port of Anchorage has considered improvements to its municipally owned facilities, including deepening the immediate approach and expanding facilities to the north along Knik Arm. The Corps of Engineers performs annual maintenance dredging to provide depths of 10.7 m at MLLW across the immediate approaches to the Port of Anchorage dock. Concerns for structural stability of the existing pile-supported dock and added non-federal maintenance dredging expense have dampened interest in deepening the face of the dock and its immediate approaches to 12 or 13 m at MLLW to serve deeper-draft vessels.

The State of Alaska has conveyed 525 hectares of tidelands, extending north of the existing port to beyond Cairn Point, to the Municipality of Anchorage. Concepts for future development of these tidelands include rerouting the Alaska Railroad tracks across Elmendorf Air Force Base to serve a new port facility at Cairn Point, where clean-swept natural depths of more than 18 m occur relatively near shore. These new facilities would be designed to export bulk products, possibly including timber and coal. Market values of these products and expenses for design and construction of the new port facilities have to date hampered any significant progress toward completion of these plans for new berths on tidelands north of the existing port. The Port of Anchorage and shippers who use the port are presently more intent on improving shoreside facilities and transportation links from the port area to the Alaskan hinterland.

5.3 Simulation of Ship Transits of Cook Inlet

5.3.1 Modeling Objectives.

The pilots of ships traveling to and from Anchorage have for decades crossed Knik Arm and Fire Island Shoals on high water by slowing their ships in lower Cook Inlet on approach or waiting at the dock on departure. Delays therefore occur in two forms: (1) extra time spent approaching Anchorage slowly in order to meet high tide at the shoals, and (2) time spent at the dock ready for departure waiting for high tide at the shoals. Both are difficult to measure directly from port records or ship's logs. The application of average tide conditions ignores the variability of the delays and assumes perfect planning of the approach. A numerical model was designed in the reconnaissance phase of this study to simulate pilot decisions and realistic application of their decisions for the transits of individual ships from their port of origin to Anchorage, their time at the dock, and their departure across the shoals. Features of the model were formulated to provide a separate measure of delays incurred for each ship transit simulated. Minor modifications to the computer code were made in the feasibility phase to improve resolution of several parameters. The following paragraphs summarize the methodology and results of simulations conducted during the feasibility phase. The application of these results in evaluating project feasibility is discussed in appendix B of this report.

5.3.2 Methodology.

The computer program relies on data derived from records of the Port of Anchorage and from information on ship departures from port of origin, cargo loads, and vessel characteristics provided by shippers. The program simulates a pilot's decision-making process by forming a plan when a simulated voyage reaches lower Cook Inlet. The plan involves slowing the vessel from its open-sea cruise speed long enough to bring the ship to Knik Arm Shoal at a particular high tide. Hourly tide heights and currents for 1991 (a typical year) were predicted at 15 locations along Cook Inlet using NOAA tide data and adaptation of NOAA tide prediction methods. The simulated pilot's plan, once formulated by the program, was executed in increments of time and motion from lower Cook Inlet all the way to the port. The effect of opposing or following tidal currents, whose speed often exceeds 3 knots, was included in this part of the simulation. The simulated time of arrival at the dock is compared to the time the ship would have arrived at full cruising speed and reported as a delay.

Upon arrival at the port, the time to berth at the dock is simulated. Time waiting for the next longshoremen's work shift to begin is also simulated. Once the scheduled work shift has begun, the unloading and reloading of the vessel's cargo is simulated. Once cargo transfer operations are complete, the vessel is considered ready to depart. A pilot plan for departure is formulated at this time, in a manner equivalent to that on approach. The plan is executed when the chosen tide conditions are reached, and the ship's departure and travel down the inlet and across the shoals are simulated. The time waiting for a work shift to begin, the cargo transfer time, and the time waiting for the tide to depart are all reported for each ship in the program output.

5.3.3 Verification.

The records of actual 1991 arrivals at and departures from the Port of Anchorage were compared to the simulated arrivals and departures in the reconnaissance phase of the study. No changes made to the code affected the fundamental computation of distances, rates, and times; therefore, the verifications of the reconnaissance phase were assumed to apply to the model as it was used in the feasibility phase. The practical criteria for judging accuracy were for simulated arrivals and departures to occur on the same high tides as recorded arrivals and departures. High tides occur approximately every 12-1/2 hours in upper Cook Inlet, so a difference of 7 hours or more implies that different high tides were involved. Simulated arrivals for 199 containership arrivals in 1991 averaged 0.5 hours difference from recorded arrival times. Simulated departures for these vessels averaged 5.7 hours difference from recorded departure times. The larger departure errors are attributed to inaccuracies in simulating the variability of work shifts and cargo transfer rates. Both differences are acceptable in terms of the evaluation criteria. The model is judged to provide an adequate measure of actual delays suffered by vessels related to crossing the shoals.

5.3.4 Results.

Fire Island Shoal presently has a natural controlling depth of -16 m at MLLW. Knik Arm Shoal has a controlling depth of -8.5 m at MLLW. The two shoals are about 20 minutes apart, in terms of the travel time of a ship approaching Anchorage. The constraint of Knik Arm Shoal is much more severe, so this shoal is directly responsible for all delays. Any approach that passes safely over Knik Arm Shoal is guaranteed also to pass safely over Fire Island Shoal with an additional 7.5 m of keel clearance.

The simulations of 1991 traffic showed that 102 Sea-Land Freight Service, Inc. (Sea-Land) ships each incurred an average 4.1 hours tidal delay. Results for 123 Totem Ocean Trailer Express (TOTE) ships show an average 3.6 hours tidal delay per ship. TOTE vessels require a flood tide for berthing so that pilots can maneuver the ships into the current for a port-side landing. Ramps for roll-on/roll-off operations are on the port side of the ships.

Simulations were made with Knik Arm Shoal deepened to simulate the operational effect of a dredged channel. Channel depths of -11, -11.5, -12, -12.5, and -13 m at MLLW were simulated. The differences between delays simulated for these alternative dredged channel depths and those simulated for the natural controlling depth of -8.5 m at MLLW reflect the delay savings achieved by the dredging.

A channel dredged to 11.5 m at low tide across Knik Arm Shoal reduced delays for the two vessel groups above to 0.8 and 1.5 hours, respectively. This amounts to an average time savings of 3.3 and 2.1 hours, respectively.

Incremental delays for containerships are presented in table 5-1. Shippers have reviewed these results and agree that they are realistic. These average time savings correspond to tangible cost savings, *i.e.* project benefits, which are described later in this report.

TABLE 5-1.--*Estimated average delay times in hours per transit*

		Without project (-8.5 m MLLW)		**With project (-11.5 m MLLW)**		**Time savings with project**	
Carrier	No. ships	Arrival delay	Departure delay	Arrival delay	Departure delay	Arrival	Departure
Sea-Land	102	2.9	0.8	0.0	0.0	2.1	1.2
TOTE	123	3.5	0.1	1.5	0.0	2.0	0.1

6. PLAN FORMULATION

6.1 Findings of Previous Studies

6.1.1 Corps of Engineers Studies.

The following reports have been published by the U.S. Army Corps of Engineers with regard to deep-draft navigation improvements in Cook Inlet.

• **House Document No. 34, 85th Congress. 1956 (Oct). "Cook Inlet and Tributaries, Alaska: Letter from the Secretary of the Army," U.S. Government Printing Office, Washington, D.C., 142 pp.**
This report to Congress summarized the review of reports by the Alaska District of the Corps, which recommended a deep-draft harbor at Anchorage and small boat harbors at Homer, Seldovia, and Ninilchik. Prior to this document, the only authorized navigation project on Cook Inlet was a boat harbor at Seldovia (originally authorized in 1945). The dock at Anchorage at that time had been constructed by the Alaska Railroad (U.S. Department of the Interior) in 1919 and rehabilitated for military uses by the U.S. Army.

• **U.S. Army Corps of Engineers (USACE), Alaska District. "Review of Report on Cook Inlet and Tributaries, Cook Inlet Shoals, Cook Inlet, Alaska - Public Meeting, Anchorage, Alaska, 30 November 1970," Anchorage, 58 pp.**
This transcript of verbal and written statements presented at a public meeting discusses the constraints to shipping caused by Fire Island and Knik Arm Shoals. Support for further studies was prevalent, but representatives from Seward pointed out that additional Federal dredging might not be as efficient as diverting cargo from Anchorage to Seward. The Corps presented some limited survey information, including results of seismic sub-bottom surveys at Knik Arm Shoal. The shoal was revealed to be formed of cobbles and boulders, covered with varying thicknesses of gravel and sand. The rocks forming the base of the shoal were assumed to be a glacial deposit.

• **USACE, Alaska District. 1978 (Jun). "Cook Inlet Shoal, Alaska, Feasibility Report, Channel Improvement for Navigation," Anchorage, 42 pp.**
This study specifically addressed the tidal delays to shipping caused by shoals along the approaches to the Port of Anchorage. A proposal for a channel improvement on Knik Arm

Shoal, referred to in the study as "Cook Inlet Shoals," was not found to be economically feasible. The average delay for 32-ft-draft vessels was estimated to be 2.9 hours, assuming a controlling shoal elevation of -15 ft MLLW. Estimated annual shipping cost savings of $513,000 associated with reduction of these delays did not offset the estimated $3,550,000 first cost and $1,000,000 annual maintenance cost of a channel 2,000 ft wide at -35 ft MLLW, centered on the Fire Island Range.

• **USACE, Alaska District. 1981 (Jan). "Southcentral Region of Alaska Deep Draft Navigation Study," Anchorage, approx. 200 pp.**
This study addressed regional waterborne commerce needs by forecasting cargo trends and assessing the cargo handling capacity of regional ports. No channel improvements in Cook Inlet were recommended. The study suggested that the Port of Anchorage may want to deepen its berths and approaches from -35 ft to -38 ft MLLW to accommodate the larger containerships, which worldwide trends indicated might serve the region in the foreseeable future. The study noted that excess capacity at Seward and Valdez could serve to alleviate future congestion at the Port of Anchorage. The tidal constraints of Fire Island Shoal and Knik Arm Shoal were not addressed. The study in general emphasized improvements to cargo handling facilities in response to future cargo throughput trends. A Federal interest in deep-draft improvements at Kodiak was identified, which led to further studies at Kodiak. These studies did not result in any new deep-draft cargo facilities at Kodiak, due primarily to the high cost of construction. Construction of a Federal breakwater to protect a harbor for commercial fishing vessels is under way on Near Island at Kodiak.

• **USACE, Alaska District. 1986 (Sep). "Interim Technical Report, Southcentral Alaska Deep Draft Navigation Study, Fire Island Shoal at Anchorage," Anchorage, 25 pp.**
This study responded to increasing concerns of maritime interests about shoaling trends along the shipping route past Fire Island. The charted shipping route passed between Fire Island and the crest of Fire Island Shoal to the west. The study demonstrated that the crest of Fire Island Shoal, composed of uniform sand, had migrated southeastward since 1941 until the -30-ft-MLLW contour encroached upon the Point MacKenzie Range marking the center of the shipping route. The study concluded that conditions at that time did not warrant any channel improvements, but that periodic surveys should be performed to monitor further shoal migration. Since this study, most ships have abandoned the Point MacKenzie Range in favor of passage to the north of the crest of Fire Island Shoal, where the 1992 controlling elevation is -48 ft MLLW over a wide area.

- **USACE, Alaska District. March 1988. "Anchorage Deep Draft Interim Technical Report," Anchorage, 77 pp.**

The study considered options to reduce the cost of waterborne commerce into and out of Anchorage. The focus was on the annual Federal maintenance dredging at the existing port and on the shoals, which caused tidal restrictions to ships approaching and departing Anchorage. The study evaluated diversion of cargo from Anchorage through other regional ports, including Whittier, Seward, and Valdez. The study found that Anchorage was preferred by shippers because Anchorage itself is Alaska's largest market for consumer goods and other supplies. Anchorage was found to offer diverse and competitive transshipment services by road, rail, and air to all parts of the State, firmly establishing the Port of Anchorage as the State's largest general cargo port and import transshipment center.

Changing the dredging geometry at the port was suggested as a means to reduce annual dredging quantities. Modifications to the dredging plan have since been accomplished and seem to have reduced the quantities. The study found no need to deepen the port adjacent to the dock. Potential future congestion at the Port of Anchorage was addressed by proposals for expansion of the existing municipal port, a new port on Fire Island, and a new port at Point MacKenzie. Indications were, however, that the existing Anchorage port facilities could handle the modest cargo increases that the study projected for several decades. Channel improvements over Fire Island and Knik Arm Shoals were considered, but neither was found economically feasible. A 1,600-ft-wide channel across Knik Arm Shoal at -35 ft MLLW was estimated to cost $5,530,000 for initial excavation and $1,580,000 for annual maintenance dredging.

- **USACE, Alaska District. 1989 (Aug). "Preliminary Reconnaissance Report, Fire Island, Anchorage, Alaska," Anchorage, 38 pp.**

This study was conducted under the small project continuing authority of Section 107 of the River and Harbor Act of 1960, as amended. The study evaluated the Federal interest and apparent feasibility of a new deep-draft port on Fire Island to serve the Anchorage area. The study was requested by the Municipality of Anchorage following a proposal for a Fire Island port development by the private group Commonwealth North. The extensive annual maintenance at the existing Port of Anchorage and the tidal constraint of Knik Arm Shoal (between Fire Island and the existing port) were cited as incentives for a Fire Island port. The causeway required for access to Fire Island was envisioned to serve as the protective breakwater for a small boat harbor. These developments were all found to be beyond the scope of Section 107 authority, and studies under General Investigations (congressionally approved) authority were recommended. This recommendation in part led to the initiation of the present study.

• **USACE, Alaska District. 1993 (Apr). "Deep Draft Navigation Reconnaissance Report, Cook Inlet, Alaska," Anchorage, 304 pp.**
This is the report that recommended the cost-shared feasibility study documented herein. The reconnaissance report addressed deep-draft navigation needs for all of Cook Inlet. The reconnaissance report identified no deep-draft needs with an immediate Federal interest other than those in Knik Arm along the approaches to the Port of Anchorage. The report concluded that a 244-m-wide channel excavated to -10.7 m at MLLW appeared feasible by current Federal standards. This alternative was estimated to cost $2,296,000 for its initial excavation. Maintenance dredging was estimated to be necessary every other year. Annual economic benefits were estimated to exceed average annual costs by a ratio of 2.3 to 1.

6.1.2 Studies by Others.

Many published studies and unpublished data collection efforts by other Federal, State, and local agencies were reviewed for this study. An annotated bibliography, a complete list of the references consulted, was compiled. The most important are listed in the References section at the end of this report. Three published studies of special relevance to the conclusions of this report are described below.

• **U.S. Coast Guard. 1991 (Sep). "Waterway Analysis for Cook Inlet West/North," Seventeenth Coast Guard District, Juneau, Alaska, approx. 150 pp.**
This report summarizes a study of current navigation practices in upper Cook Inlet and the adequacy of the current system of aids to navigation. The Coast Guard investigators found that deep-draft vessels approaching Anchorage no longer follow the Race Point Range to the south of the crest of Fire Island Shoal. Pilots instead now guide their vessels north of the crest, avoiding shallower water and associated tidal delays. The report concludes that the navigation aid system along the approaches to Anchorage should be modified to accommodate this practice. Figure 2-2 in section 2 shows the present system of aids to navigation, as reviewed by the Coast Guard. A summary of the actions proposed by the Coast Guard in this study follows.

a. NEAR-TERM ACTIONS (AS OPERATIONS AND EQUIPMENT PERMIT)

(1) Increase the nominal range of East Foreland Light from 7 nautical miles (nmi) to 9 nmi.
(2) Increase the nominal range of Moose Point Light from 5 nmi to 9 nmi.
(3) Increase the nominal range of Fire Island Light 6 from 5 nmi to 7 nmi.
(4) Increase the nominal range of Point Possession Light from 7 nmi to 9 nmi.
(5) Add a radar beacon (RACON) to Moose Point Light.
(6) Add a RACON to Fire Island Light 6.
(7) Research and submit requests to chart the various radio/microwave towers along Cook Inlet, particularly from Anchor Point to Kenai and around the city of Anchorage.
(8) Initiate numerous minor chart and publication corrections.

b. MID-TERM ACTIONS (WITHIN 2 TO 3 YEARS)

(1) Increase the nominal range of East Foreland Light from 9 nmi to 15 nmi using shore power.
(2) Establish a 15-nmi light on North Foreland using shore power.
(3) Establish a 12-nmi light with a RACON in the drainage of the Little Susitna River near Magot Point in approximate position 61°16' N., 150°30' W.

c. LONG-TERM ACTIONS (WITHIN 5 YEARS)

(1) NOAA should conduct an extensive hydrographic survey of Upper Cook Inlet, particularly around Fire Island Shoal, to determine the best passage affording safest water around this shoal *(accomplished in 1992)*.
(2) Based on NOAA findings, the Coast Guard could possibly reconstruct or move Terrestrial Ranges as appropriate around Fire Island to make use of the best channel.
(3) Relocate Cook Inlet Lighted Buoy 3 to indicate the preferred channel.

- **CH_2M-Hill. 1991 (Dec) (draft). "Fire Island Deep Water Port Facility - Constructability Analysis, Market Potential, and Economic Feasibility Analysis," Alaska Industrial Development and Export Authority (AIDEA), Anchorage, approx. 200 pp.**
This report was commissioned by AIDEA, an incorporated State agency, to determine the advisability of State purchase of private lands on Fire Island for future construction of a deep-draft port facility. The port was to be designed for export of coal and other bulk materials. The primary site for the port was Race Point, a prominence on northwest Fire Island. Race Point is near natural depths of 60 feet and greater. The constraint of Knik Arm Shoal would not affect a Fire Island port, and this circumstance was cited as a major incentive for the proposed Race Point development. An expensive causeway from Point Campbell to Fire Island would be required. Point Campbell is now developed as popular park lands and suburban housing. The causeway expense, its environmental impacts, and its potential impact on traffic and noise on Point Campbell would be highly controversial. The ultimate conclusion of the study and the peer review process that followed was that a port development on Fire Island was not economically feasible. Since a Federal interest may have existed in both channel improvements and in breakwater construction at Fire Island, this conclusion was critical to the direction of the present Corps study.

- **Peratrovich, Nottingham, and Drage, Inc. 1993 (Jan). "Southcentral Ports Development Project," Alaska Department of Commerce and Economic Development (ADCED), Anchorage, approx. 200 pp.**
This study was initiated by the State of Alaska during the present Corps effort. The ADCED managers accepted suggestions from the Corps for the contract scope of work. The study has, as a result, been a significant source of information on the current status of ports in the region and projections of cargo throughput into and out of Cook Inlet ports and competing ports in Southcentral Alaska.

The study recommends specific port developments, particularly for export of timber products and coal. Three options for coal export are discussed: (1) through the existing coal export terminal at Seward, (2) through a proposed new bulk terminal at Port MacKenzie (across Knik Arm from Anchorage), and (3) through a new bulk terminal north of the existing Port of Anchorage. The coal-related findings of the study are controversial. Though the draft report appears to favor a new port at Port MacKenzie for long-term efficiency, reviewers presented many pages of comments and facts in support of the other options. Timber products export was less controversial, since this resource is distributed so that many ports may efficiently provide export capacity with limited capital improvements. The report projects the Port of

Anchorage to continue as the State's leading containerized cargo port for the next 40 years or more. An excavated channel across Knik Arm Shoal is described as a worthy measure for improving transportation efficiency through the Port of Anchorage to Southcentral Alaska.

6.2 Field Data Collection and Analysis, 1992

The field data collection efforts during the reconnaissance study that preceded this feasibility study are summarized in the following paragraphs. An independently scheduled hydrographic survey by NOAA in July 1992 provided an opportunity for the NOAA ship *Rainier* to support measurements by the Corps. The measurements included current profiles (surface to bottom) with an acoustic Doppler current profiler (ADCP), water temperature and conductivity profiles, profiles of optical backscatter (*i.e.*, turbidity), water samples at various depths and locations, samples of bottom materials, and acoustic echo amplitude (suspended sediment concentration) profiles.

NOAA provided more than 120 bottom material samples from across the survey area that had been collected routinely for the sake of chart annotations. The Corps collected additional bottom material samples in the immediate vicinity of Knik Arm Shoal. The spring-loaded grab sampler notably could collect no sediment in seven tries at the highest point of Knik Arm Shoal. This usually indicates a very hard bottom. All samples collected between Point Woronzof and Fire Island were classified by appearance and tested for grain size distribution. The median grain size for most samples was on the order of 0.4 mm, or in the range of medium to fine sand. A few coarser samples were collected near the crest of Knik Arm Shoal and near the tip of Point Woronzof.

Current measurements were made by a continuously recording broad-band 614-kilohertz ADCP system. Current data was continuously provided for every 1 m of depth and approximately every 10 m along tracks that crossed Knik Arm Shoal and vicinity. Courses across the waterway were repeated on the flood and the ebb flows surrounding a single slack tide (either high or low tide). The ADCP current data indicates that current speeds in the upper water column can exceed 4 knots, but the average (surface to bottom) current speed during maximum flood or ebb flows is typically about 3 knots.

Profiles of conductivity and temperature were measured at points across the project area. Salinity, the amount of dissolved material in the water, and density are readily computed from concurrent temperature and conductivity measurements. Temperatures and salinities were generally uniform with depth. Typical July temperatures were around 14.5 °C. Salinities varied from 6 to 11 parts per thousand, tending to be saltier west of Fire Island. Salinities of the central Gulf of Alaska are on the order of 32 parts per thousand.

Water samplers of 6 liters volume were lowered on the cable that held the optical backscatter sensor. The number of samples and the depths at which they were captured varied according to total water depth and vertical variability revealed by acoustic data. The water from the samples was subsequently filtered, the filtrate weighed, and the grain size distribution determined. The weight (mass) of the filtrate provided a direct measure of the suspended sediment concentration at the place and time of the sample collection. Concentrations varied widely, from tens of milligrams sediment per liter of water (mg/L) to a maximum of nearly 4,000 mg/L.

The grain size distributions of the water sample filtrates indicate that suspended materials are predominantly silt, with some occasional fine sand mixed in (especially closer to the bottom). The median grain size of suspended material was typically from 0.004 millimeters (mm) to 0.016 mm. Silt was not found except as a small fraction of bottom samples in the study area, indicating that currents are too energetic to allow any settlement of this fine material without almost immediate resuspension.

6.3 Field Data Collection and Analysis, 1994

The NOAA ship *Rainier*, in response to the concerns of maritime interests for changing conditions at Knik Arm Shoal, as expressed in the reconnaissance report, returned in May 1994 to survey the project area. The survey revealed a continuation of trends detected in the 1992 survey. North Point Shoal was shown to have essentially merged with Knik Arm Shoal on its north side below the 8-m contour, effectively closing off the north side to deep-draft vessels. The U.S. Coast Guard advised mariners accordingly, though most pilots of deep-draft vessels had ceased passage north of the shoal since 1992.

Corps measurements in 1994 were organized to resolve seasonal changes on and near Knik Arm Shoal over a specific grid of transect lines and sample locations (see figure A-9 in appendix A, part 1). ADCP current profiles were repeated across the area during flood and ebb flows in May, July, and early October. An attempt was made to measure currents in the extremely cold conditions of late November, but ice proved too hazardous to deploy the expensive ADCP. Figure 2-5 shows a representative transect across Knik Arm at Knik Arm Shoal and illustrates the complexity and depth dependence of tidal currents across the area.

The findings of 1992 ADCP measurements were generally duplicated in 1994, and no seasonal trends, beyond predictable astronomical variations, were detected.

Additional profiles of temperature and conductivity were measured. These measurements were discussed in section 2 of this report. Seasonal variations in water temperature followed expected trends. Some indication of higher salinity and stratification in early spring was detected. Water samples were also collected and filtered to determine suspended sediment concentration and grain size distribution of suspended materials. No significant trends in suspended sediment concentration were apparent in the data, though specialists still believe summer concentrations are higher than mid- to late winter concentrations.

Bed samples were collected across the grid, with emphasis on the central portion along the Fire Island navigation range (see figure A-14, appendix A, part 1). No seasonal trends were detected, and the distribution of bed material grain size found in 1992 was again encountered. Mobile material was found to be medium sand of about 0.4 mm diameter. Coarser material and difficulties in sample collection were found on higher parts of Knik Arm Shoal. No indications of accumulation of finer material were found anywhere in the project area at any time.

Precisely positioned surveys of depths along the lines of the grid (figure A-9, appendix A, part 1) were repeated in May, July, early October, and (with partial success) in late November. Profiles of depths from these surveys were superimposed for comparison, as shown in figures A-10, A-11, and A-12. Some indication of seasonal change in 1994 was detected in deeper water west of Knik Arm Shoal, but no change within horizontal and vertical position tolerances of the work were detected on the higher elevations of Knik Arm Shoal. NOAA survey data from 1978, 1982, 1992, and 1994 along the same lines were compared (see figures A-4 to A-7), with the same general conclusion. No significant changes on the higher elevations of Knik Arm Shoal were apparent from 1978 to 1994, though major changes occurred in other areas, such as on the north side and in deeper water west of the shoal.

Contours of survey data all across the project area from the 1978, 1982, 1992, and 1994 NOAA surveys were superimposed for comparison (figure A-3, appendix A, part 1) and contours of hydrographic change between these years were plotted (figures A-4 to A-8). These comparisons show a trend of scour west of Knik Arm Shoal along the Fire Island Range. The south side of the shoal on the Fire Island Range and the area to the east along the Fire Island Range show no significant change. The accretion north of the shoal is apparent in these comparisons. Some change is also noted southeast of the shoal several hundred meters beyond the Fire Island Range toward Woronzof Shoal, as shown by the 1992 contour at -10 m MLLW.

6.4 Alternatives Involving No Excavation

6.4.1 Improved Aids to Navigation.

Pilots use the present system of visual ranges to locate their ships with respect to hazardous submerged shoals and points of land in all weather conditions. A pair of lighted buoys, removed in winter, mark Knik Arm Shoal. Experience has shown that the stoutest of buoy moorings has little chance of survival in midwinter ice conditions. In its 1991 "Waterway Analysis," the Coast Guard found that the present system could be improved and recommended a series of enhancements. The most significant of these involves the Global Positioning System (GPS) of satellite navigation. Horizontal positioning accuracy of 3 m is possible through an adaptation of GPS technology known as differential GPS (DGPS). DGPS uses a stationary reference receiver on a known location to transmit corrections for satellite-related errors to a second receiver. Radio telemetry is the usual means for transmitting the corrections between receivers, but commercially available arrangements vary and have not yet become standardized. Positioning accuracy with DGPS is within a few feet for a receiver in motion, such as a ship at sea (Hurn 1989). The Coast Guard has converted some of its outmoded radio locator beacons to serve as DGPS shore stations, broadcasting corrections. The Coast Guard plans to make DGPS available in upper Cook Inlet in 1996.

This highly accurate knowledge of ship's position is most useful to pilots if they know the position of nearby hazards to navigation with the same accuracy. Paper charts and manual position plotting do not provide this accuracy, but commercially available electronic chart display (ECDIS) systems make full use of DGPS and other electronic navigation aids (for example, RACON signals). A computer and sophisticated graphics display provide the pilot with a chart showing with equal accuracy the ship's position and that of all nearby points of interest. The combination of DGPS and ECDIS technology in upper Cook Inlet would significantly improve the safety of the constricted passage into the Port of Anchorage.

6.4.2 Increased Frequency of Surveys.

More accurate charts of the shoals along the approaches to the Port of Anchorage would improve the safety and efficiency of ship transits and allow more accurate application of ECDIS technology. NOAA has responsibility for hydrographic surveys of navigable waters in upper Cook Inlet and in the past has usually repeated surveys about every 10 years. Recent public attention to the shoals of upper Cook Inlet has led NOAA to reevaluate this policy and plan surveys in Knik Arm every 5 years. An authorized Federal channel would provide the Corps of Engineers with authority to accomplish annual or even more frequent surveys in the immediate vicinity of the channel. Chart publication is a valued public service provided at many Corps projects around the U.S. coast where the sea bottom is constantly shifting (*e.g.*, the Intercoastal Waterway), even though the primary objective is to plan for maintenance dredging. Local maritime interests could also accomplish regular surveys, but the precision, quality assurance, and institutional documentation of NOAA would be difficult to duplicate.

6.4.3 Modifications to Shipping Practices.

Barges serving the Port of Anchorage suffer much less delay in crossing the shoals than the deeper-draft vessels, and often cross without any delay. Tug and barge operations can serve most of Alaska's many medium- and shallow-draft ports, or lighter ashore where there is no port at all. This mode of maritime transportation has been a mainstay for many Alaskan coastal communities for decades. The large annual throughput at Anchorage is more efficiently accomplished by faster, larger-capacity vessels, however. The containerships of Sea-Land and TOTE have above average speed and power for vessels of their class, provided by the ship owners after many years' experience in the Alaskan trade. A shift to shallower-draft vessels involves reduced capacity, reduced speed at sea, and a significant reduction in efficiency. No major shift in shipping practices into upper Cook Inlet appears practical.

6.4.4 Diversion of Cargo to Other Ports.

Anchorage and Southcentral Alaska can be served by road and rail transshipment from ports not affected by the shoals of upper Cook Inlet. The interior of Alaska can be served by highway transshipment through the Port of Valdez. The Port of Whittier already receives barged cargo destined for Anchorage and Interior Alaska via the Alaska Railroad. Whittier has deep water near shore and is ice-free all year, but has little available upland staging area, severe winter snowfall, and no road access. A plan to provide some road use of the railroad route to Whittier is under consideration by the Alaska Department of Transportation and Public Facilities (ADOT&PF). This potential new access appears to be aimed primarily at tourists and recreational visitors rather than heavy commercial traffic. The quantities of containerized cargo coming into Anchorage are more efficiently offloaded by high capacity equipment at the Port of Anchorage, where ample stacking area is available adjacent to the dock and multiple transshipment modes are readily available.

The Port of Valdez has underutilized capacity for containerized cargo. Containers and break-bulk cargo can be trucked from Valdez to Fairbanks and Interior Alaska. The Richardson Highway from Valdez to Fairbanks has severe snowfall and avalanche hazards in the Thompson Pass area near Valdez. The Port of Anchorage has dominated containerized cargo transshipment to Fairbanks for more than a decade since Valdez has had a container terminal, in part because Anchorage has both rail and road access without the severe winter snowfall or avalanche hazards of Valdez. Diversion of Fairbanks cargo from Anchorage to Valdez appears unlikely.

The Port of Seward can handle break-bulk, containerized, and dry-bulk (coal) cargo for transshipment to or from Anchorage and the Interior by either the Seward Highway or the Alaska Railroad. Resurrection Bay at Seward has deep water near shore and is ice-free all winter. Both the highway and the railroad have steep grades and significant winter snowfall. Some of the Seward Highway grades and avalanche risks have been reduced in recent years by realignment of the road and avalanche prevention measures. Summer recreational traffic is intense along the Seward Highway, and the ADOT&PF continues to make road improvements. The mountain range between Seward and Anchorage will always be a deterrent to overland transportation of heavy and large-volume cargo. The prospect of diverting some containerized cargo from the Port of Anchorage to Seward for transshipment to Anchorage has been discussed among shippers and Port of Seward officials, but no such diversion has taken place. No regularly scheduled large-volume containership service is now available at Seward. The Southcentral Port Development Project (Peratrovich, Nottingham, and Drage 1993) concluded that the Port of Anchorage was the most efficient terminal for receipt of containerized cargo for Anchorage and the surrounding region. This conclusion appears to be confirmed by commercial decisions driven by market pressures.

6.5 Channel Excavation Alternatives

6.5.1 Channel Location and Orientation.

Analysis of successive NOAA surveys through 1994 and seasonal Corps surveys during 1994, geophysical and geotechnical explorations, tidal hydrodynamics, and sediment transport in

Knik Arm indicate that a channel positioned along the southern flank of Knik Arm Shoal, as shown in figure 6-1, would have the least initial dredging quantity and minimum maintenance dredging requirement. Knik Arm Shoal shows no significant change along the Fire Island Range since 1955. The sandy area west of the shoal shows significant scour. The sum of all evidence is that the glacially deposited material of upper Knik Arm Shoal is able to withstand the tidal energy.

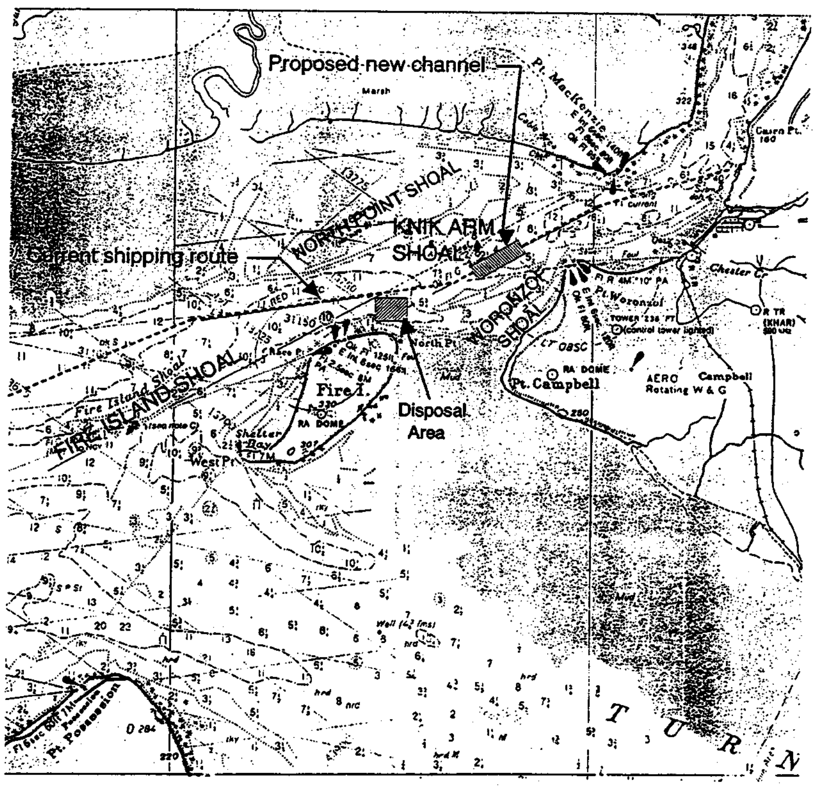


FIGURE 6-1.--Current shipping area in upper Cook Inlet, with proposed channel and disposal area locations.

The Fire Island Range was chosen as the nominal center line for channel excavation. This orientation was found to have minimum initial dredging requirements, while being aligned with prevailing currents. Evidence is strong that the channel alignment is naturally clean swept. Deepening along Fire Island Range would allow average currents to increase along the excavation. There is some evidence of historical change in this part of Knik Arm (see figure A-3 in appendix A, part 1); therefore, some periodic maintenance appears probable during the project life.

6.5.2 Channel Width.

Channel width is generally determined as a function of ship beam (maximum ship width). TOTE containerships have beams of 32 m, and one tanker calling at the Port of Anchorage has a beam of 32.3 m. Passing traffic at the shoal is easily avoided, so the channel can be designed for one-way traffic. An allowance must be made for maneuvering conditions in the channel with regard to cross-currents, wind, and waves. Another allowance must be made for the limited accuracy of the pilot's ship position with respect to the channel margins. The combination of these factors constitutes the "sweep path" or lane over which some part of a ship may pass in normal conditions. The extreme winter conditions at Knik Arm Shoal call for an additional allowance for the adverse effect of ice on ship navigability and possible concurrent strong winds and low visibility. The buoys marking the shoal are not in place during icy months, so the pilot's knowledge of the location of this hazard is much less precise. An additional width allowance must be made for these extreme circumstances. Finally, a margin of safety beyond this extreme sweep path must be incorporated.

Allowances for each of the above channel width considerations lead to a width of 245 m, as explained in more detail in appendix A, part 1. This width is conservative in terms of major marine fairways around the world (PIANC 1980). However, discussions with Cook Inlet shippers and pilots indicate 245 m is a minimum acceptable width during crossings of Knik Arm Shoal during periods of ice and low visibility when keel clearance is near minimum. Pilots unanimously prefer a much wider channel. Another 30 m channel width was added on each side as an allowance for shoaling to maintain the authorized channel width between dredgings. This allowance is intended to address uncertainties in the prediction of maintenance dredging and to provide added safety during the most extreme conditions. The total channel width recommended for excavation is 305 m. Slope stability analysis, based on the geotechnical characteristics of the material to be excavated, indicates side slopes of 1 vertical to 4 horizontal would be stable in the ambient conditions at Knik Arm Shoal (see appendix A, part 2).

6.5.3 Channel Depth.

The natural controlling depth across Knik Arm Shoal is 8.5 m at MLLW. Pilots require 2.5 m of gross keel clearance for a safe crossing above the least bottom depth along their route. Sea-Land containerships, fully loaded, typically have 10 m of draft on arrival at the dock. The depth generally available at the face of the dock at the Port of Anchorage is 10.7 m at MLLW at this time. Less keel clearance is required at rest over the soft bottom at the dock, but because of the present depth limitation, 10 m is a practical maximum draft for vessels regularly serving the port. Port of Anchorage officials have mentioned in meetings that they are exploring the possibility of deepening the face of the dock, so this presently practical criterion may change in the foreseeable future. Tides at Anchorage cause an 8-m to 9-m variation in depth twice daily, so pilots can now realize 2.5 m of keel clearance into the port without any dredged channel by waiting for high tide. The optimum channel depth at Knik Arm Shoal is an economic choice, by comparison of the incremental expense of waiting for a higher tide level to the expense of deeper excavation.

Computer simulations were the principal tool for evaluating various channel depths with regard to tidal delays and related expenses. Knik Arm Shoal is only minutes away from the Port of Anchorage; thus ships generally arrive at the dock at near the same tidal stage at which they crossed the shoal. This fact led to investigation of channel excavations to depths near 11 m MLLW, roughly the same depth as at the Port of Anchorage. Ships' delays were simulated for channel elevations of -11 m, -11.5 m, -12 m, -12.5 m, and -13 m MLLW. Dredging quantities and initial excavation costs were computed for these elevations, with an additional 1.5 m excavation as an allowance for inaccuracies of dredging and hydrographic surveying, for uncertainties in the prediction of maintenance dredging, and as added safety during extreme conditions on Knik Arm Shoal. Dredged material quantities were thus estimated for 305-m-wide excavation elevations at -12.5 m, -13.0 m, -13.5 m, -14.0 m, and -14.5 m MLLW, with side slopes of 1 vertical to 4 horizontal. Costs at these four alternative excavation depths were compared to benefits estimated on the basis of computer simulations for "pilot depths" of -11 m, -11.5 m, -12 m, -12.5 m, and -13 m MLLW. An excavation depth of -13.0 m (-11.5 m "pilot depth") proved to have the maximum net economic benefits.

6.5.4 Dredging Considerations.

A suitable open-water disposal area for dredged material lies north of Fire Island in depths exceeding 20 m, as shown in figure 6-1. This area is the center of an area of continuing scour and associated dispersion of bed material. The mobile bed material found at the disposal site is slightly more coarse than the loose surface material found at the excavation site, but is equivalent to the coarser fraction of the sub-bottom material at the excavation site. Dredged material discharged in open water at this site would descend to the bottom in minutes and then be dispersed over a period of days or weeks to the deeper waters of Knik Arm in line with prevailing tidal currents. There is little chance that this material would be deposited in the excavation or on the shore of Fire Island.

The quantities of material to be dredged and the likelihood of encountering occasional cobbles or small boulders (less than 0.5 m), while working in the strong currents and high tidal ranges of Knik Arm, indicate a mechanical clamshell dredge would be a practical excavating tool. This type of equipment is deployed each summer for maintenance dredging at the Port of Anchorage. Stronger currents at Knik Arm Shoal and intermittent strong winds and rough seas would require a heavier clamshell bucket and additional anchors for the dredge. The equipment required for dredging at Knik Arm Shoal would be suitable for maintenance dredging at the Port of Anchorage.

6.5.5 Cost Estimates.

It will probably not be possible to accomplish the dredging at Knik Arm Shoal under the same contract and with the same equipment as the maintenance dredging at the Port of Anchorage. This feasibility report considers the cost of Knik Arm Shoal dredging as an independent contract, with the full cost of transporting equipment from the Pacific Northwest to the Anchorage area. Should both dredging projects be accomplished by the same contract, the net benefits for the Knik Arm Shoal project would probably increase. Table 6-1 presents estimated initial costs for the four depth alternatives along the optimum alignment, at the level of accuracy appropriate for economic optimization.

TABLE 6-1.—*Estimated first cost of alternative elevations, Knik Arm Shoal Channel*

Elevation m (MLLW)	mob/ demob ($)	Excav. qty. (m^3)	Dredging ($)	Surveys ($)	Final design ($)	Contract admin. ($)	Total ($)
-12.5	485,000	623,500	2,882,000	80,000	200,000	356,000	4,003,000
-13.0	485,000	848,600	3,915,000	80,000	200,000	356,000	5,036,000
-13.5	485,000	1,116,100	5,156,000	80,000	200,000	356,000	6,277,000
-14.0	485,000	1,424,600	6,593,000	80,000	200,000	356,000	7,714,000
-14.5	485,000	1,764,800	8,200,000	80,000	200,000	356,000	9,321,000

7. EVALUATION OF ALTERNATIVES

7.1 Alternatives Involving No Excavation

The alternatives for improving navigation in upper Cook Inlet that were introduced in the previous section are evaluated in this section. Nonstructural alternatives include no action, improved aids to navigation, increased frequency of surveys, modifying shipping practices, and diverting cargo to ports other than Anchorage.

7.1.1 No Action.

Continuing the present circumstances at Knik Arm Shoal would lead to increasing transportation costs stemming from shipping delays. Population increases and increased productivity in Southcentral Alaska will require increased throughput of containerized and general cargo at the Port of Anchorage. Additional ship transits of the shoal and vicinity will be required to deliver this cargo. Any resource exports that may occur, such as the proposed shipment of refined iron from a new plant at Point MacKenzie or coal from the interior or the Matanuska Valley, will further increase the number of annual ship transits of the shoal area. An increased number of ship transits will be accompanied by a proportional increase in delay time and cost of transportation to and from the port. Increased traffic will also increase pressure for pilots to be timely on arrival at the Port of Anchorage and thus increase the tendency to reduce margins of safety in crossing Knik Arm Shoal. A misjudgment could result in grounding and potential spill of fuel and cargo into Knik Arm.

7.1.2 Improved Aids to Navigation.

The enhancement of pilots' ability to locate their ships with respect to Knik Arm Shoal and other hazards in upper Cook Inlet would reduce risks of grounding. The proposed system of DGPS positioning and shipboard ECDIS navigation would provide ships' positions within a few meters of true earth coordinates. Highly accurate ships' positions would not provide major increases in safety or transportation efficiency unless the positions of hazards were known with equivalent precision. Channel marker buoys at Knik Arm Shoal are removed each fall so the ice will not destroy them. They are replaced each spring in positions that respond to any known changes in bathymetry. Well-marked hazards and precise ships' positions give pilots the information needed to steer a safe course. Improved aids to navigation are being installed by the U.S. Coast Guard as an independent measure. This measure will not significantly affect the delays caused by shallow water at Knik Arm Shoal.

7.1.3 Increased Frequency of Surveys.

NOAA has indicated its intent to increase its frequency of surveys and chart publication from 10 to 5 years for the project area. Recent NOAA surveys made 2 years apart (1992 and 1994) detected significant change along navigation routes in parts of Knik Arm. The marked route north of Knik Arm Shoal had effectively closed for deep-draft ships in that time. This is clear evidence that changeable areas, such as Fire Island Shoal and North Point Shoal, can cause new navigation problems within 2 to 3 years of the last survey. The route south of the crest of Knik Arm Shoal is consistently stable between surveys dating back to 1955. The present 5-year repetition of surveys in Knik Arm appears adequate to detect changes of significance in that area to deep-draft ships approaching the Port of Anchorage. A survey that reveals a dramatic shift in preferred navigation routes, such as the 1992 survey, may be followed by a discretionary survey in 1 or 2 years to see the trend through to its conclusion. In summary, present NOAA policies regarding repeated surveys and chart revisions appear to be responsive to the needs of mariners in Knik Arm.

7.1.4 Modifying Shipping Practices or Diverting Cargo to Other Ports.

These options can occur only through market pressures. History and recent decisions by shipping companies indicate that the Port of Anchorage will continue for decades to be Alaska's largest transshipment center for containerized goods. The problems associated with containerships crossing Knik Arm Shoal will also continue for decades unless artificial channel improvements are accomplished. The population of Anchorage is by far the largest concentration in Alaska and could not be served more efficiently from another port. Alternative port facility locations in the Anchorage area have been investigated at length, and no more efficient port site has been found that is economically feasible or otherwise financable for construction. No diversion of cargo to other ports is likely to occur with or without navigation improvements in Knik Arm.

7.2 Channel Dredging

7.2.1 Channel Geometry.

The formulation of a functional channel design was summarized in section 6 and is discussed in more detail in appendix A, part 1, and in appendix B. Initial dredging and future maintenance dredging quantities are minimized by following the alignment of the existing Fire Island navigation range (see figure 6-1). This location avoids shoaling trends in adjacent areas of the inlet and lies along the center line of an area with no natural change in existing conditions. No other channel locations take advantage of stable bottom conditions or have significant advantages in terms of steering deep-draft vessels toward Anchorage. The channel bottom width is a practical choice, based on safety margin for maneuvering the vessels that now cross the shoal bound for Anchorage. An additional 30-m width on each side is added to the 245-m guaranteed width for the ships at hand, as an allowance for the uncertainties in the prediction of maintenance dredging at 5-year intervals.

Channel depth is the only geometric parameter with which economic benefits vary such that a cost-effective optimum can be objectively identified. The economically optimum channel depth is 11.5 m at MLLW, as discussed in section 6. An additional 1.5 m would be excavated to allow for the inaccuracies of hydrographic surveying and dredging and for the uncertainties in the maintenance dredging analyses. The total initial excavation depth is thus 13.0 m at MLLW. This depth requires an initial excavation of 848,600 m^3. This material would be discharged in open water approximately 4 km west of the excavation just north of North Point on Fire Island.

7.2.2 Economic Benefits.

Economic benefits from the proposed channel excavation on Knik Arm Shoal would come primarily from reduction in transportation costs. Cost savings attributable to the channel excavation would result from reduced fuel consumption by ships serving Anchorage, more efficient stevedore and dock facility scheduling (in both Anchorage and Tacoma), reduced administrative costs, reduced vessel and port maintenance requirements, and reduced insurance costs. Opportunity cost of time benefits would result from reduced vessel transit times. A detailed explanation of the derivation of these benefits is presented in appendix B. The following paragraphs summarize the procedures and findings of the economic analysis.

Channel benefits were estimated by calculating the transportation costs for both with- and without-project conditions. Historical and existing commodity movements through the

Port of Anchorage were examined. Existing commodity movements were used to develop the benefits for this project. The Port of Anchorage in this analysis is assumed to continue indefinitely as the dominant port of entry for general cargo imports to Southcentral and Interior Alaska.

The prospect for additional ship traffic into Knik Arm bound for the proposed coal export facility at Port MacKenzie is noted, but is not directly applied in the analysis at the feasibility level. Likewise, the alternative proposal to expand the Port of Anchorage northward for export of coal is noted, but not applied to the project total ship traffic. The success of either of these plans would significantly increase the savings realized by the channel and enhance its economic feasibility; however, the possibility of coal exports could be 10 or more years away.

Petroleum tonnage at the Port of Anchorage recently has been of the same order of magnitude as containerized cargo, but a much smaller number of vessel trips per year are involved. Benefits attributable to the transportation of petroleum products are thus much smaller than those from containerized cargo and were not addressed in this feasibility report.

The computer simulation model of ship transits of Cook Inlet, described in subsection 5.3, was run using 1991 tide data. The year 1991 was assumed to be an average year for tides. From data provided by the Port of Anchorage and the shippers, an average seasonal load for the vessels was developed for the model run. The findings of the simulations of the ship transits into Cook Inlet during 1991 were applied to estimate the average delays per vessel trip without the project. The delays per trip that would occur with the channel in place were also estimated. The difference between these two estimates was applied as the transit time savings achieved by excavation of the channel. Incremental costs associated with these time savings for each of the two scheduled container services now using the Port of Anchorage were next estimated as the National Economic Development benefits of the project (table 7-1).

The average annual cost of excavating, monitoring, and maintaining the channel is estimated as $264,000, with an annual interest of 7-3/4 per cent. This estimate assumes that maintenance dredging of half the initial excavation quantity at the Knik Arm Shoal would be done every 5 years during the life of the project. The estimates for initial excavation and for maintenance of the channel are discussed further in appendix A, part 1.

Total average annual benefits are estimated at $1,769,000, which exceed average annual costs by $1,099,000. The ratio of benefits to costs is 2.6. The plan therefore appears economically feasible and worthy of construction.

TABLE 7-1.--*Transportation savings benefits (January 1996 price level, channel at -11.5 m MLLW)*

Item	**Amount**
Sea-Land Service, Inc.	
Fuel savings	$287,000
Administrative savings	34,000
Stevedore castoff savings	80,000
Stevedore savings, Anchorage	99,000
Stevedore savings, Tacoma	64,000
Container savings	90,000
Total Sea-Land	$654,000
Totem Ocean Trailer Express (TOTE)	
Fuel savings	$405,000
Administrative savings	53,000
Stevedore castoff savings	9,000
Stevedore savings, Anchorage	278,000
Stevedore savings, Tacoma	90,000
Container savings	222,000
Insurance savings	50,000
Wharf savings	8,000
Total TOTE	$1,115,000
Total transportation savings	**$1,769,000**

7.2.3 Environmental Impacts.

Suspended sediment concentrations would increase during dredging and open-water disposal. Ambient suspended sediment concentrations regularly exceed 2,000 mg/L in summer, when dredging would take place. Benthic and planktonic organisms are extraordinarily sparse in Knik Arm because the high turbidity prevents light penetration into the water, which precludes photosynthesis. Nekton (swimming organisms) generally are migrating to and from the streams at the head of Knik Arm or are predators of the migrating species. The natural suspended sediment concentrations in Knik Arm are not much less than those in the heart of dredged material discharge plumes. The high tidal ranges in Knik Arm create strong tidal currents which regularly exceed 4 knots. Dredged material would be nearly identical to natural material at the disposal site. Neither temperature nor salinity would be measurably affected. Benthic life at the disposal site is nearly nonexistent because of the high natural turbidity, extraordinary turbulence, and continuously mobile bed material. No tidelands or salt marshes are near enough to be measurably affected by the dredging operations. Marine birds and mammals are rarely found near either the proposed excavation site or the disposal site and can easily avoid these operations. Dredging-induced turbidity increases at either the excavation or the disposal site would be rapidly dispersed by the strong natural turbulence and would not have measurable impacts on marine organisms.

The dredging and disposal operations would be noticeable to salmon set net fishermen on Fire Island and near Point MacKenzie, but neither the operation of the set nets nor the catch would be measurably affected. Normal precautions for safe navigation are sufficient to prevent collisions between the dredge and other vessels in Knik Arm. The power cable of the Chugach Electric Association would be precisely located, marked by temporary buoys, and avoided with extreme caution during dredging operations.

*7.2.4 **Implementation Prospects.***

This study was conducted under the authority of resolutions adopted by the U.S. Senate Committee on Public Works and the U.S. House of Representatives Committee on Public Works on 27 April 1970 and 2 December 1970, respectively, as a part of the Corps of Engineers' "General Investigations" (GI) Program. Successful completion under the GI Program can lead to a recommendation for congressional authorization for project construction and subsequent operation and maintenance by the Corps of Engineers as provided by Public Law (PL) 99-662. Approval of this feasibility report would lead to a report by the Chief of Engineers and endorsement by the Secretary of the Army to the appropriate Senate and House committees in response to the study resolutions. Project implementation would then follow congressional authorization and subsequent funding for construction, operation, and maintenance.

Prior to actual construction, a Project Cooperation Agreement would be signed by representatives of the Corps and the non-federal sponsor, describing the terms for and responsibilities of the Federal Government and the sponsor for construction of the project, its operation and maintenance, and cost sharing. In accordance with the cost-sharing provisions of PL 99-662 for these kinds of projects, the non-federal sponsor must agree to pay 25 percent of the cost of construction during the construction, and an additional 10 percent of the cost of construction over a period not to exceed 30 years, with credit given against this 10 percent for lands, easements, rights-of-way, reallocations, and dredged material disposal areas. The current estimated cost of construction at 1997 price levels is $5.342 million, of which $1.87 million would be the non-federal share, including $1.336 million initially and $534,000 over a period not to exceed 30 years. The initial dredging of the project could take place in the same year that construction funds are appropriated, which in accordance with normal Corps budgetary processes would be Fiscal Year 1998. Costs above are reported at estimated 1997 prices, in keeping with the stated desires and intense efforts of non-federal interests at the time of this printing to enable construction in 1997.

8. THE RECOMMENDED PLAN

8.1 Description

The navigation rovement plan with the optimum characteristics, based on present knowledge of conditions surrounding Knik Arm Shoal and deep-draft shipping to the Port of Anchorage, is illustrated in figure 8-1. The channel requires the Fire Island visual range to be realigned by the U.S. Coast Guard. No other aids to navigation need be added in Knik Arm to accommodate safe navigation. Field measurements and other information indicate the excavation is located in an area of long-term scouring and would not be subject to shoaling. Hydrographic surveys already scheduled every 5 years by NOAA would be sufficient to monitor the channel, except for Corps surveys estimated to cost $40,000 during each of the first 2 years after the initial excavation. The plan has the following dimensions:

Channel length	2,000 m
Channel width (authorized)	245 m
Channel width (initially excavated)	305 m
Channel bottom elevation (authorized depth)	-11.5 m MLLW
Initial excavation elevation	-13.0 m MLLW
Side slopes	1 vertical: 4 horizontal
Initial excavation quantity	848,600 m^3

8.2 Real Estate

The plan requires no acquisition of lands, easements, rights-of-way, or upland disposal areas, since both the excavation and the disposal area are in waters over which the Federal Government exercises navigational servitude. No staging area or relocations of utilities would be required.

8.3 Cost Allocation

Incremental costs for the recommended plan, itemized as Federal and non-federal costs, are summarized in table 8-1. The National Economic Development (NED) costs are summarized in table 8-2. These are the costs used to evaluate the economic feasibility by Federal standards. Table 8-3 presents the required cost sharing apportionment at estimated 1997 price levels, the earliest practical time of construction.

TABLE 8-1.--*Cost estimate for recommended plan (1996 price levels)*

Item	Quantity	Unit	Unit cost ($)	Cost ($)	Contingency (%)	Contingency ($)	Total ($)	NED costs ($) Federal (65%)	NED costs ($) Non-federal
Channel excavation									
Mobilization and demobilization	job	each	404,200	404,200	20	80,800	485,000	315,250	169,750
Dredging	848,600	m^3	3.84	3,262,500	20	652,500	3,915,000	2,544,750	1,370,250
Associated surveys	6	each	11,100	66,000	20	14,000	80,000	52,000	28,000
Total construction contract				3,731,800		747,200	4,480,000	2,912,000	1,568,000
LERRD	job	each	0	0	0	0	0	0	0
Engineering and design (federal)	job	each	167,700	167,700	20	33,300	200,000	130,000	70,000
Construction management (federal)	job	each	296,700	296,700	20	59,300	356,000	231,400	124,600
Total project cost				**4,196,200**		**839,800**	**5,036,000**[a]	**3,273,400**	**1,762,600**

[a] The fully implemented cost at 1997 price levels (*i.e.*, at the earliest possible time of construction) is estimated to be $5,342,000. The federal share (65 percent) of this cost is $3,472,300 and the non-federal share is $1,869,700.

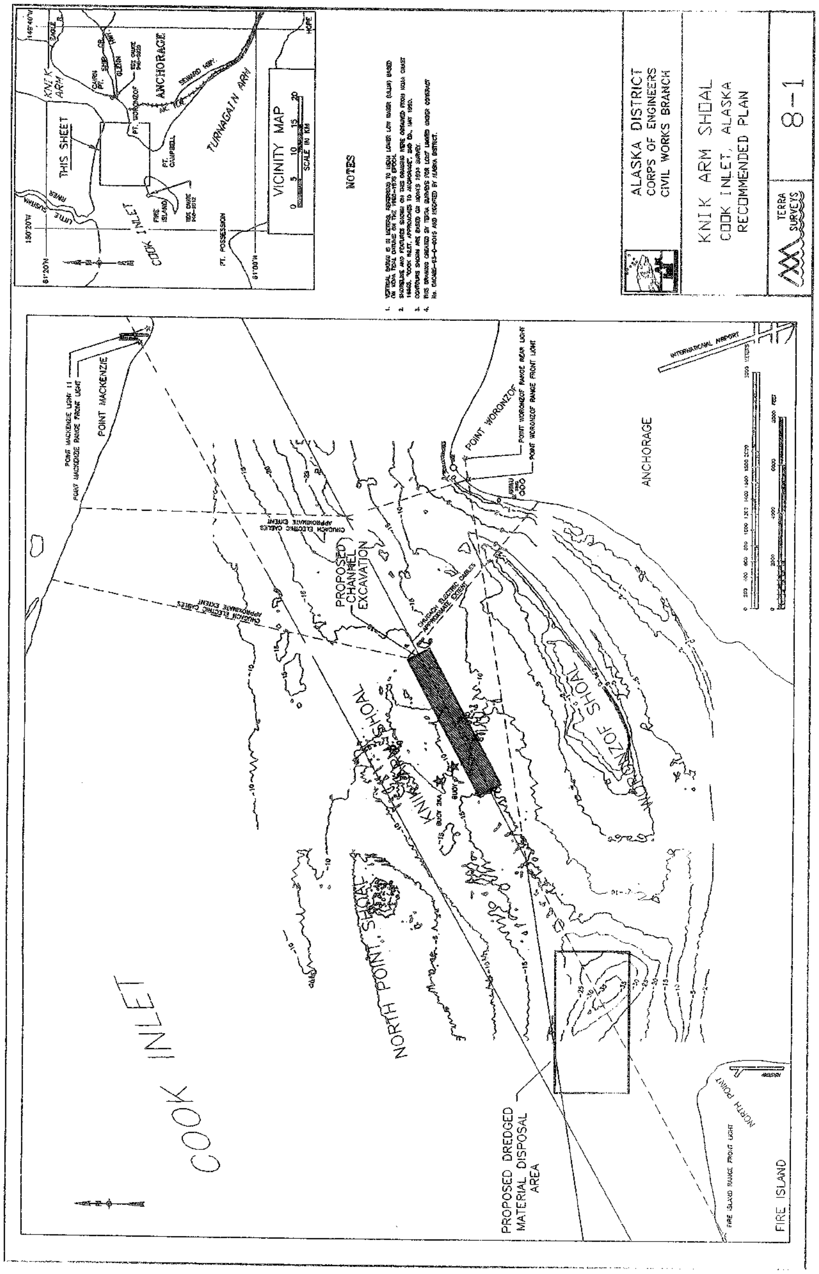

COOK INLET
NORTH POINT SHOAL
KNIK ARM SHOAL
WORONZOF SHOAL
PROPOSED CHANNEL EXCAVATION
PROPOSED DREDGED MATERIAL DISPOSAL AREA
FIRE ISLAND
POINT MACKENZIE
POINT WORONZOF
ANCHORAGE
THIS SHEET
KNIK ARM
TURNAGAIN ARM
VICINITY MAP
NOTES
ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH
KNIK ARM SHOAL
COOK INLET, ALASKA
RECOMMENDED PLAN
TERRA SURVEYS
8-1

TABLE 8-2.-- *Summary of project NED costs (1996 price levels)*

Item	Cost ($)
Total NED construction cost	5,036,000
NED interest during construction	82,000
NED investment cost	5.118,000
Annual value of NED investment (50 years @ 7.75%)	406,000
Annual NED maintenance cost	264,000
Total annual NED cost	670,000

TABLE 8.3--*Cost-sharing apportionment at fully funded (1997) price levels*

	Federal	Non-federal	Total
Initial costs	$4,006.000	$1,336,000	$5,342,000
Reimbursement	-534,000	534,000	
Final cost	$3,472,000	$1,870,000	$5,342,000

8.4 Economic Benefits

The benefits for the recommended plan are summarized in table 7-1. The net annual benefits (total annual benefits less average annual costs) for the recommended plan are $1,099,000. The recommended plan had the greatest net benefits of any of the alternatives investigated. The ratio of total annual benefits to average annual costs is 2.6.

8.5 Non-federal Sponsorship

The non-federal sponsor for construction of the project must enter into an agreement with the Federal Government to share the cost of construction as itemized in table 8-1. The non-federal sponsor, in the case of the recommended Knik Arm Shoal channel, would not be responsible for maintenance or operation of any project features. The Federal Government would be fully responsible for the maintenance of the channel. The non-federal sponsor must agree to hold the Federal Government harmless for liability associated with the use of the project by the public. The agreement must be signed and the full share of non-federal funds made available before preparations for project construction can begin, following congressional authorization.

The Municipality of Anchorage has indicated by correspondence dated March 18, 1996, included in appendix D of this report, that it is willing to act as non-federal sponsor for implementation of this recommended plan, in collaboration with the Alaska Department of Transportation and Public Facilities. Both government entities have an economic interest in the channel improvements recommended at Knik Arm Shoal. Both are legally and financially capable of satisfying the requirements for non-federal sponsorship and have expressed an interest in doing so. An assessment of the prospective sponsor's financial capability is included in appendix D.

8.6 Project Implementation

The draft version of this Feasibility Report was reviewed by the Corps' North Pacific Division, in Portland, Oregon, and Headquarters, in Washington, DC. A Project Guidance Memorandum, prepared after a Feasibility Review Conference, specified revisions and additions to be incorporated by the Alaska District in the report. The revised draft of the Feasibility Report and Environmental Assessment was made available for review to the general public. Responses to public comments and associated changes to the report are included in this printing. The North Pacific Division will review this final District Engineer's report, including responses to public comments. Upon approval, the North Pacific Division Engineer will forward the report for Washington-level review. Revisions resulting from this review will be incorporated in the Chief of Engineers' report to the U.S. Congress. Authorization to construct the project and appropriation of funds by Congress will be necessary prior to final design and construction of the project.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Investigations of physical conditions and economic needs show that Federal participation in navigation improvements at Knik Arm Shoal in upper Cook Inlet is justified. Improvements consisting of a channel excavated 305 m wide at -13.0 m MLLW, approximately 2,000 m long, would provide year-round access to the Port of Anchorage for deep-draft ships at the -11.5-m-MLLW level over a width of 245 m. The fully-funded cost at 1997 price levels, the earliest practical time of construction, is estimated to be $5,342,000.

The proposed channel alignment, according to field measurements and comparison of historical surveys, is expected to require maintenance dredging no more than every 5 years. Sensitivity analyses testing the effect of hypothetical maintenance dredging requirements do not change the apparent optimum dimensions. The project consists only of general navigation features, and no purely non-federal features or local service facilities are required to achieve full economic benefits. No lands, easements, rights-of-way, relocations, real estate for borrow areas or dredged material disposal areas (other than in waters subject to Federal navigational servitude), or historical preservation, mitigation, or data recovery costs are required to construct, operate, or maintain the project according to the recommended plan.

Average annual benefits for the plan are estimated to be $1,769,000. These benefits are estimated to exceed the average annual cost by $1,099,000, for a benefit/cost ratio of 2.6. Environmental effects of implementation appear to be acceptable. Federal costs at 1997 price levels are estimated to be $3,472,000, which is 65 percent of the total estimated costs for design and construction. The Federal Government is authorized to initially pay an additional amount not to exceed 10 percent of the total cost, which must be reimbursed by the non-federal sponsor within 30 years. The initial Federal cost, including the additional 10 percent of the total cost, will be $4,006,000. The Municipality of Anchorage has indicated its intent to act as non-federal sponsor and has proven it has financial capability.

9.2 Recommendations

I recommend that the plan proposed in this report be implemented with the participation of the Federal Government at an estimated final Federal cost of $3,472,000. The plan is recommended with such modifications as in the discretion of the Commander, U.S. Army Corps of Engineers, may be advisable. This recommendation applies only if the non-federal sponsor agrees to:

a. Provide all lands, easements, rights-of-way, and suitable borrow and dredged or excavated material disposal areas, and perform or ensure the performance of all relocations determined by the Federal Government to be necessary for the construction, operation, and maintenance of the general navigation features.

b. Provide all improvements required on lands, easements, and rights-of-way to enable the proper disposal of dredged or excavated material associated with the construction, operation, and maintenance of the general navigation features. Such improvements may include, but are not necessarily limited to, retaining dikes, weirs, bulkheads, embankments, monitoring features, stilling basins, and dewatering pumps and pipes.

c. Provide, during the period of construction, a cash contribution equal to the following percentages of the total cost of construction of the general navigation features:

(1) 10 percent of the costs attributable to dredging to a depth not in excess of 20 feet;

(2) 25 percent of the costs attributable to dredging to a depth in excess of 20 feet but not in excess of 45 feet;

(3) 50 percent of the costs attributable to dredging to a depth in excess of 45 feet.

d. Repay with interest, over a period not to exceed 30 years following completion of the period of construction of the Project, an additional 0 to 10 percent of the total cost of construction of general navigation features depending upon the amount of credit given for the value of lands, easements, rights-of-way, relocations, and borrow and dredged or excavated material disposal areas provided by the Non-federal Sponsor for the general navigation features. If the amount of credit exceeds 10% of the total cost of construction of the general navigation features, the Non-federal Sponsor shall not be required to make any contribution under this paragraph, nor shall it be entitled to any refund for the value of lands, easements, right-of-way, relocations, and dredged or excavated material disposal areas, in excess of 10% of the total cost of construction of the general navigation features.

e. For so long as the Project remains authorized, operate and maintain any dredged or excavated material disposal areas, in a manner compatible with the Project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government.

f. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the Non-Federal Sponsor owns or controls for access to the general navigation features for the purpose of inspection, and, if necessary, for the purpose of operating and maintaining the general navigation features.

g. Hold and save the United States free from all damages arising from the construction, operation, and maintenance of the Project and any betterments, except for damages due to the fault or negligence of the United States or its contractors.

h. Keep, and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the Project, for a minimum of three years after completion of the accounting for which such books, records, documents, and other evidence is required, to the extent and in such detail as will properly reflect total cost of construction of the general navigation features, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 CFR Section 33.20.

i. Perform, or cause to be performed, any investigations for hazardous substances as are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the construction, operation, and maintenance of the general navigation features. However, for lands that the Government determines to be subject to the navigation servitude, only the Government shall perform such investigations unless the Federal Government provides the Non-federal Sponsor with prior specific written direction, in which case the Non-federal Sponsor shall perform such investigations in accordance with such written direction.

j. Assume complete financial responsibility, as between the Federal Government and the Non-federal Sponsor, for all necessary cleanup and response costs of any CERCLA-regulated materials located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the construction, operation, or maintenance of the general navigation features.

k. To the maximum extent practicable, perform its obligations in a manner that will not cause liability to arise under CERCLA.

l. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for construction, operation, and maintenance of the general navigation features, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act.

m. Comply with all applicable Federal and State laws and regulations, including, but not limited to, Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 USC 2000d), and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army."

n. Provide a cash contribution equal to the following percentages of total historic preservation mitigation and data recovery costs attributable to commercial navigation that are in excess of one percent of the total amount authorized to be appropriated for commercial navigation:

(1) 10 percent of the costs attributable to dredging to a depth not in excess of 20 feet;

(2) 25 percent of the costs attributable to dredging to a depth in excess of 20 feet but not in excess of 45 feet;

(3) 50 percent of the costs attributable to dredging to a depth in excess of 45 feet.

I also recommend that the U.S. Coast Guard review the present navigation practices and problems that occur along the approaches to the Port of Anchorage and, with a view toward the recommended channel improvement, design and implement revisions to the existing system of navigation aids. I further recommend that the National Oceanic and Atmospheric Administration continue to conduct surveys and publish new nautical charts of Knik Arm in the area surrounding the recommended plan according to the agency's present practice at 5-year intervals. Recommendations to the U.S. Coast Guard and NOAA are advisory in nature and are made with the understanding that administrators of these agencies will make independent decisions regarding needs and actions in upper Cook Inlet.

These recommendations reflect the policies governing formulation of individual projects and the information available at this time. They do not necessarily reflect the program and budgeting priorities inherent in the local and State programs or the formulation of a national civil works water resources program. Consequently, the recommendations may be changed at higher review levels of the executive branch outside Alaska before they are used to support congressional authorization and funding.

Date: 5 April 1996

Peter A. Topp
Peter A. Topp
Colonel, Corps of Engineers
District Engineer

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FINDING OF NO SIGNIFICANT IMPACT AND ENVIRONMENTAL ASSESSMENT

COOK INLET DEEP-DRAFT NAVIGATION

In accordance with the National Environmental Policy Act of 1969, as amended, the U.S. Army Engineer District, Alaska, has assessed the environmental effects of the following action:

Cook Inlet Deep-Draft Navigation

The project will dredge a channel through the Knik Arm shoal in upper Cook Inlet to allow greater access for deep-draft shipping into Anchorage Port facilities. Deep-draft vessels must wait for higher tidal stages before crossing the shoals in Knik Arm. Tidal ranges in Knik Arm, the largest in the United States, exceed 30 feet.

The channel will be 305 meters (1,001 feet) wide and 2,000 meters (6,562 feet) long. The channel will allow one lane of traffic and will be safe in the worst of icy winter conditions. Initial dredging will be to -13.0 meters (42.6 feet) at Mean Lower Low Water (MLLW), which is the design required for safe passage of deep-draft vessels. The initial dredging quantity is estimated at 848,600 cubic meters (1,109,918 cubic yards). Maintenance dredging of approximately 397,600 cubic meters (520,037 cubic yards) is anticipated every 5 years.

All dredged material will be disposed of in deep water near Fire Island. The majority of the dredged material is sand and gravel with some small boulders. The disposal site has similar substrate. The initial channel dredging is expected to take 3 months during the ice-free period. Dredging will be by mechanical clamshell dredge, which will deposit the dredged material onto a split-hull hopper barge.

Based on the analysis presented in the environmental assessment, Section 404(b)(1) evaluation under the Clean Water Act, and State and Federal agency reviews, no significant environmental impacts will occur from the shoal dredging and disposal project. The project is consistent with State coastal zone management plans. The proposed action does not constitute a major Federal action significantly affecting the quality of the human environment. Therefore, an environmental impact statement is not necessary for the proposed Cook Inlet Deep-Draft Navigation Project.

Peter A. Topp	1 April 1996
Peter A. Topp Colonel, Corps of Engineers District Engineer	(Date)

Cook Inlet Deep-Draft Navigation
Environmental Assessment

CONTENTS

COOK INLET DEEP-DRAFT NAVIGATION
ENVIRONMENTAL ASSESSMENT

1. PURPOSE AND NEED OF PROPOSED ACTION

The Alaska District is studying the feasibility of dredging a channel through the Knik Arm Shoal in upper Cook Inlet to allow greater access for deep-draft shipping into Anchorage port facilities (see figure 2-1 in the main report). Deep-draft vessels must wait for higher tidal stages before crossing the shoals in Knik Arm. Tidal ranges in Knik Arm exceed 30 feet, the highest in the United States.

2. DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

2.1 Proposed Action

The proposed channel is 305 meters (1,001 feet) wide and 2,000 meters (6,562 feet) long. These dimensions are the result of intensive economic optimization. The channel allows for only one lane of traffic and would be safe in the worst of icy winter conditions. Initial dredging would be to -13.0 meters (-42.6 feet) at 0 Mean Lower Low Water (MLLW), which is the design draft required by a deep-draft vessel. The initial dredging quantity is estimated at 848,600 cubic meters (1,109,918 cubic yards). Maintenance dredging is anticipated every 5 years at approximately 50 percent of the original dredging volume, or 397,600 cubic meters (520,037 cubic yards).

The proposed dredged material disposal site is a deep-water area near Fire Island. The majority of the dredged material is sand and gravel with some boulders. The disposal site has similar substrate. The initial channel dredging is expected to take 3 months during the ice-free period. Dredging would be by mechanical clamshell dredge, which would deposit the dredged material onto a dump-scow barge.

2.2 No-Action Alternative

The no-action alternative is the without-project condition. Currently, navigation aids such as tidal markers, as well as more sophisticated surveys and Global Positioning System (GPS) instruments, are used to chart the shipping channel. Shipping into the Port of Anchorage would continue to be scheduled to avoid the lowest tides. Costs and lost time factors are involved with these delays. Without the proposed channel, shipping during storms, in strong currents, and in heavy ice may have less room to maneuver and increase the potential for damages to the vessel or cargo.

3. AFFECTED ENVIRONMENT

3.1 Physical Environment

Upper Cook Inlet is divided geographically into northern and central regions by the East and West Forelands. The project is in upper Cook Inlet; therefore, physical and natural resources for this region are discussed. Upper Cook Inlet is bordered by extensive tidal marshes, lowlands with many lakes, and glacier-carved mountains. The inlet at its head divides into two arms, Knik Arm and Turnagain Arm. Knik Arm averages 50 feet deep for about half its length and then shallows rapidly to a mudflat. Turnagain Arm shallows within the first 10 miles to a large mudflat cut by many tidal channels. Tidal marshes are prevalent around the mouth of the Susitna River; in Chickaloon, Trading, and Goose Bays; the Palmer Hayflat at the head of Knik Arm; and Potter Marsh within the Anchorage coastal area. The surrounding mountains are very steep and rugged with distinct tree lines. Higher elevations of the ranges may be covered with ice fields and valley glaciers. Approximately 90 percent of the Kenai, Chugach, and Talkeetna Mountains are nonforested. Sitka spruce and western hemlock are the dominant tree species in the Chugach Range. Interior spruce-birch forests dominate the remaining forest lands located on lower slopes and in stream valleys. Nearly 75 percent of the Cook Inlet-Susitna lowlands are forested with white spruce, paper birch, and quaking aspen. Cottonwood is common along major streams. Black spruce occurs in wet or burned areas; muskeg, usually treeless, occasionally supports some stunted black spruce (Gatto 1976).

Tidal flats in the northern part of upper Cook Inlet extend toward the inlet from about the mean high tide line and consist of exposed mud flats vegetated only by algae. Above the tide line, vegetation is dominated by various grass species, such as creeping alkali grass and seaside arrow-grass interspersed with patches of mud colonized by glasswort. The marsh community has a diverse interspersion of wetland, wet meadow, and grass-forb communities.

Circulation and local tidal currents are important factors in the distribution of nutrients, which determine productivity in the inlet. Because of the large tidal fluctuation in a shallow, narrow basin, waters of the upper inlet are well mixed laterally, longitudinally, and vertically with each tidal cycle. In the summer, with a large inflow of glacial meltwater in tributary streams, there is net outward movement of upper inlet water of as much as a mile with each tidal cycle. In winter, however, with reduced runoff in tributary streams, there is practically no net outflow from the upper inlet (Murphy *et al.* 1972). The Matanuska, Knik, and Susitna Rivers contribute approximately 70 percent of the fresh water discharged annually into the inlet. Much of the suspended sediment in these rivers originates at higher altitudes as glacial flour or by freezing and thawing of bedrock and unconsolidated material. Glacial streams in the Matanuska-Susitna area normally contain as much as

2,000 mg/L suspended sediment during the summer. The rivers entering Knik Arm annually discharge 13 to 19 million tons of sediment, primarily in the summer (Rosenberg *et al.* 1967).

Fresh-water runoff into the inlet is an important source of nutrients and sediments. Large quantities of nitrate, nitrite, silicate, and suspended sediments with particulate organic carbon enter the inlet with fresh water. The large inflow of fresh water dilutes and reduces salinity and phosphate concentration around river mouths. Salinity of upper Cook Inlet waters varies from 6 parts per thousand in the summer to slightly more than 20 parts per thousand in the winter.

Considerable effort was made to classify the sediments in the proposed channel and disposal site. A marine geophysical survey, using precision navigation and echo sounding, sub-bottom profiling, and continuous seismic reflection profiling was undertaken to determine the bottom and sub-bottom conditions of the Knik Arm Shoal area in Cook Inlet. In addition, core samples were taken to determine precise sediment particle sizes and formation type and depth. This information is detailed in appendix A, part 2. A summary of results follows:

a. The crest of the shoal is at a depth of 7 to 8 meters below sea level and has 4 to 5 meters of relief above the surrounding sea floor.

b. The surficial and subsurface sediments are glaciofluvial deposits composed of sand and gravel with some cobbles and boulders less than 0.5 meters in diameter. There also appear to be pockets of fine-grained sediments (silty-clay). The glaciofluvial deposits were formed by the retreating glaciers. The pockets of silty clay are marine deposits formed between glacial periods. These deposits were encountered in only one borehole, G-1, at a depth of 7.5 feet extending to the bottom of the hole at 23.5 feet. The majority of this formation is outside the channel alignment.

3.2 Biota

Biota present primarily in upper Cook Inlet north of the forelands are discussed in this section.

3.2.1 Plankton and Intertidal Organisms. The abundance of plankton is a measure, not only of the productivity of a body of water, but also of the food supply for higher forms. Phytoplankton surveys (Rosenberg *et al.* 1967, Murphy *et al.* 1972, Evans *et al.* 1970) in Cook Inlet indicate that numbers of species and abundance increase as one moves down the inlet toward the ocean. Primary production appears to be limited in the upper inlet by reduced light penetration from the high suspended sediment loads. The high silicate content of incoming sediments and the high silicate content of inlet waters appear to favor the growth of diatoms, which are by far the dominant phytoplankters.

Plankton surveys of upper Cook Inlet list species of cladocera, copepoda, protozoa and rotifera in Knik Arm. The relatively poor zooplankton diversity and abundance (except copepods) suggest that debris, silt, and low salinity at certain times of the year severely restrict the survival of zooplankton.

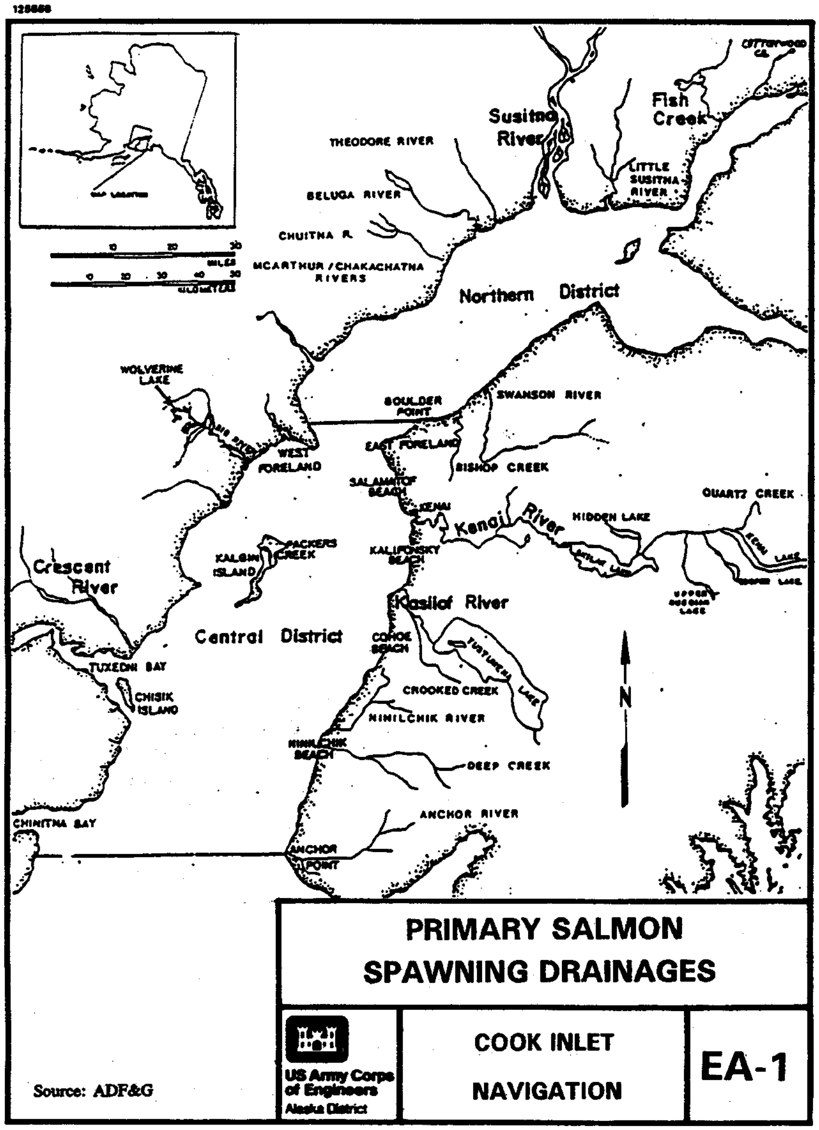
Intertidal benthic invertebrates from upper Cook Inlet comprise a mixture of marine and freshwater animals. Beach cores indicated that the only living marine infaunal organism was the small estuarine clam, *Macoma bathica*. Nudibranchs (*Placida dendritica*) were collected from macroscopic algae beds (*Vaucheria longicaulis*), which form a zone at least 50 meters wide on mudflats between Anchorage and Point Campbell. Numerous epifaunal true bugs and a few adult flies were found in the marsh south of Point Woronzof. One adult beetle and a small beetle larva also were found. Terrestrial organisms (especially insects) may comprise half of salt marsh animals. Detritus is the main energy source in salt marshes, although benthic algae are consumed by some snails and birds. Gammarid amphipods are present in this general region (U.S. Dept. of Army 1979).

Subtidal benthic organisms are sparse in upper Cook Inlet. Burial of organisms by silt, subtidal erosion, and scouring of the seafloor by sediment and ice, exceptionally high turbidity, rapid currents, low temperatures, and low and fluctuating salinity all combine to create an exceptionally severe estuarine environment (U.S. Dept. of Army 1979).

Energy for the moderate production of fish and epibenthic invertebrates occurring in Knik Arm is probably provided by organic detritus from adjacent marshes and streams.

3.2.2 Fish. Upper Cook Inlet supports a sport fishery of five species of salmon, as well as Dolly Varden and eulachon. These anadromous fish are usually taken from local creeks and rivers rather than Knik and Turnagain Arms, except for eulachon, which are dip-netted from tidal channels in Turnagain Arm. This part of upper Cook Inlet, comprising Knik Arm drainages, the Anchorage area, and east Susitna River drainages, is the focus of a sport fishing effort in which 390,088 angler days were expended in 1993. This effort comprises 21 percent of the total sport fishing angler days for the Southcentral region of the State. Adult salmon are the most sought-after species (Mills 1994).

Upper Cook Inlet is divided into the Central and Northern Districts for commercial fisheries management. The main salmon spawning drainages are shown in figure EA-1. The Northern District is split into two subdistricts (General and Eastern) north of the forelands. The major salmon stream in this area is the Susitna River. Set gill-nets are the only gear permitted in the Northern District. The commercial fishing season generally extends from June until the end of September. In 1993, salmon harvested in the northern district totaled 291,723 fish (Ruesch and


Susitna River
Fish Creek
THEODORE RIVER
BELUGA RIVER
LITTLE SUSITNA RIVER
CHUITNA R.
MCARTHUR / CHAKACHATNA RIVERS
Northern District
WOLVERINE LAKE
BOULDER POINT
SWANSON RIVER
WEST FORELAND
EAST FORELAND
BISHOP CREEK
SALAMATOF BEACH
KENAI
Kenai River
HIDDEN LAKE
QUARTZ CREEK
Crescent River
KALGIN ISLAND
PACKERS CREEK
KALIFONSKY BEACH
Kasilof River
Central District
CANOE BEACH
TUXEDNI BAY
CHISIK ISLAND
CROOKED CREEK
NINILCHIK RIVER
NINILCHIK BEACH
DEEP CREEK
ANCHOR RIVER
CHINITNA BAY
ANCHOR POINT
N
PRIMARY SALMON SPAWNING DRAINAGES
US Army Corps of Engineers
Alaska District
COOK INLET
NAVIGATION
EA-1
Source: ADF&G

Fox 1993). The Northern District set gill-net harvest data from 1966 through 1993 is presented in table EA-1. There are 135 set-net fishing permits for the Northern District. Eight set-net sites are located around Fire Island.

Typically the upper Cook Inlet harvest represents approximately 5 percent of the statewide salmon catch. The Northern District catch is approximately 5 percent of the upper Cook Inlet harvest. The 1993 commercial harvest of 5.3 million salmon in upper Cook Inlet was somewhat above the average of 4 million, but substantially below the 1992 harvest of 10.6 million. The 1994 salmon harvest in upper Cook Inlet was 4 million fish. The 1995 harvest also was expected to decline (Dept. of Fish and Game 1995).

The personal use and subsistence fishery in upper Cook Inlet is divided into several salt-water set gill-net areas and two fresh-water dip-net salmon fishing areas (figure EA-2). The annual bag and possession limit is 25 salmon per permit holder (Dept. of Fish and Game 1995).

Other fish in upper Cook Inlet north of the forelands include Dolly Varden (which are distributed throughout Cook Inlet), herring, smelt, and small flounder. Although starry flounder, Pacific tomcod, and lemon or English sole are recorded from the Point Woronzof region, demersal fish probably occur in very low populations due to severe environmental conditions and lack of food. Dolly Varden, humpback whitefish, and five species of salmon migrate into local creeks. Anadromous stickleback (threespine and ninespine) have been reported in Knik Arm (U.S. Dept. of Army 1979).

A beach-seining fish sampling program was conducted in Knik Arm for the environmental analysis of the proposed Knik Arm Crossing Project (Dames and Moore 1983). Eighteen species of fish were captured, which added to the knowledge of the fish populations in this part of the inlet. The species included all of the above mentioned fish with a few exceptions. Bering cisco and saffron cod were caught consistently enough to question, in the researcher's mind, whether the humpback whitefish and the Pacific tomcod were correctly identified near Point Woronzof. Other fish not previously identified included the longfin smelt, Pacific herring, ringtail snailfish, yellowfin sole, Pacific staghorn sculpin, and eulachon (Blackburn 1977). Crustacea caught in the seine nets included primarily crangonid shrimp, mysidacea, amphipoda, and isopoda.

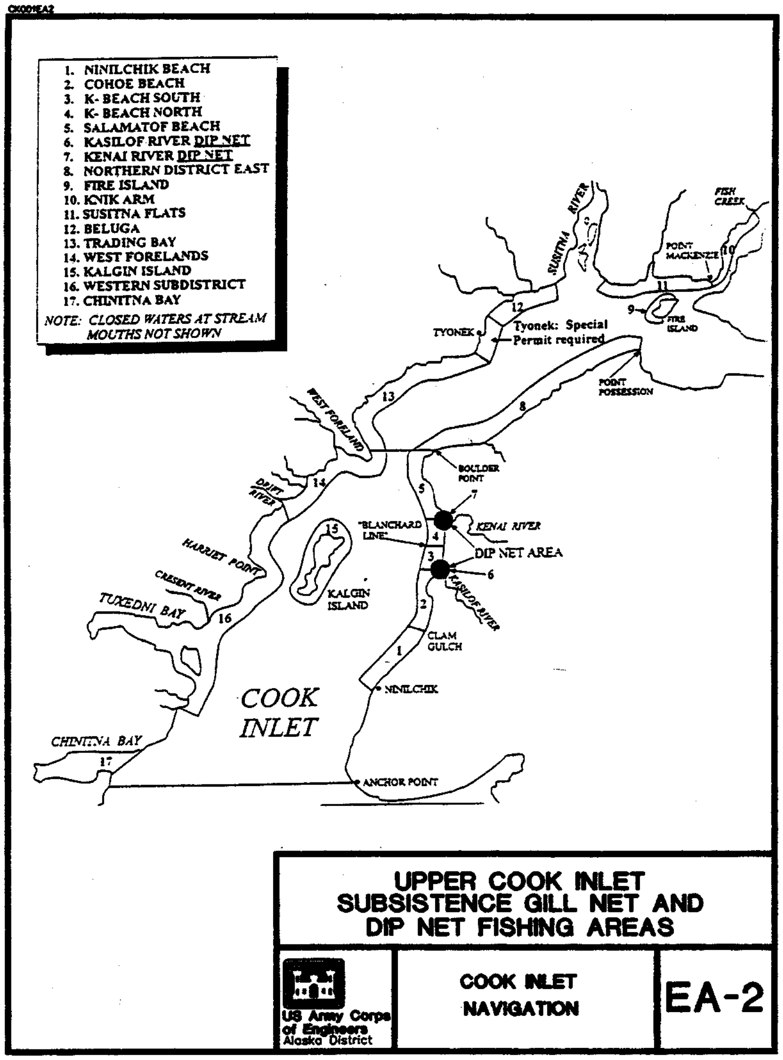
3.2.3 Birds. Pintails, mallards, green-winged teal, and lesser Canada geese are the most common waterfowl using northern Cook Inlet salt marshes and wetlands. Plover, sandpipers, yellowlegs, dowitchers, and phalaropes are among the most common shorebirds. Pintails and mallards are usually the first migrants to arrive in mid-April. Highest population levels occur during the spring when the marshes are heavily used by lesser Canada and snow geese, ducks, and occasional swans and

TABLE EA-1.--*Upper Cook Inlet commercial salmon harvest by gear type and area, 1966-1993*

Year	Central District drift gill net		Central District set gill net				Northern District set gill net		Total
			East side		Kalgin/West side				
	Number	%	Number	%	Number	%	Number	%	
1966	2,203,180	47.0	1,538,621	32.8	327,585	7.0	619,610	13.2	4,688,996
1967	1,184,228	62.6	364,541	19.3	135,249	7.1	208,947	11.0	1,892,965
1968	2,612,714	52.6	1,189,117	24.0	269,670	5.4	890,987	18.0	4,962,488
1969	652,011	59.0	247,514	22.4	125,541	11.4	80,910	7.3	1,105,976
1970	1,641,429	62.1	460,676	17.4	189,798	7.2	349,340	13.2	2,641,243
1971	739,835	66.3	153,374	13.7	125,986	11.3	97,251	8.7	1,116,446
1972	1,207,217	54.1	643,323	28.8	160,443	7.2	220,605	9.9	2,231,588
1973	1,105,354	62.3	299,616	16.9	130,542	7.4	237,824	13.4	1,773,336
1974	827,141	52.2	471,210	29.7	118,352	7.5	168,141	10.6	1,584,844
1975	1,457,277	66.5	340,625	15.5	173,510	7.9	220,446	10.1	2,191,858
1976	2,142,563	59.4	1,012,991	28.1	183,952	5.1	270,096	7.5	3,609,602
1977	2,626,455	64.9	912,023	22.5	223,362	5.5	285,347	7.1	4,047,187
1978	3,304,925	64.6	1,085,009	21.2	265,302	5.2	464,150	9.1	5,119,386
1979	1,199,085	62.3	308,166	16.0	216,395	11.2	202,400	10.5	1,926,046
1980	2,165,142	53.7	911,327	22.6	269,750	6.7	687,951	17.1	4,034,170
1981	1,672,457	57.8	558,657	19.3	180,338	6.2	484,282	16.7	2,895,734
1982	4,139,886	65.7	1,530,966	24.3	303,249	4.8	322,441	5.1	6,296,542
1983	4,621,365	68.2	1,582,746	23.4	277,819	4.1	289,944	4.3	6,771,874
1984	2,290,273	59.3	758,174	19.6	298,978	7.7	515,766	13.4	3,863,191
1985	3,127,467	55.7	1,671,259	29.8	472,238	8.4	341,272	6.1	5,612,236
1986	4,969,254	62.0	2,291,571	28.6	296,292	3.7	460,468	5.7	8,017,585
1987	6,088,837	58.3	3,656,473	35.0	342,782	3.3	361,608	3.5	10,449,700
1988	5,217,224	60.7	2,687,819	31.2	274,593	3.2	422,229	4.9	8,601,865
1989	819	0.0	4,686,002	84.2	304,209	5.5	575,068	10.3	5,566,098
1990	3,166,684	62.6	1,391,505	27.5	174,066	3.4	325,035	6.4	5,057,290
1991	1,514,519	52.0	884,539	30.4	212,787	7.3	299,876	10.3	2,911,721
1992	6,994,103	66.2	3,152,807	29.8	203,403	1.9	214,271	2.0	10,564,584
1993	2,861,352	53.9	2,043,409	38.5	152,440	2.9	291,723	5.5	5,303,924
Average[a]	2,654,765	59.7	1,190,533	24.8	226,497	6.3	345,589	9.3	4,415,717

[a] Figures from 1989, the year of the Exxon *Valdez* oil spill, are excluded from the average.

Source: Alaska Department of Fish and Game.


1. NINILCHIK BEACH
2. COHOE BEACH
3. K- BEACH SOUTH
4. K- BEACH NORTH
5. SALAMATOF BEACH
6. KASILOF RIVER DIP NET
7. KENAI RIVER DIP NET
8. NORTHERN DISTRICT EAST
9. FIRE ISLAND
10. KNIK ARM
11. SUSITNA FLATS
12. BELUGA
13. TRADING BAY
14. WEST FORELANDS
15. KALGIN ISLAND
16. WESTERN SUBDISTRICT
17. CHINITNA BAY
NOTE: CLOSED WATERS AT STREAM MOUTHS NOT SHOWN
SUSITNA RIVER
FISH CREEK
POINT MACKENZIE
FIRE ISLAND
TYONEK
Tyonek: Special Permit required
POINT POSSESSION
WEST FORELAND
BOULDER POINT
DRIFT RIVER
"BLANCHARD LINE"
KENAI RIVER
DIP NET AREA
HARRIET POINT
CRESENT RIVER
KALGIN ISLAND
KASILOF RIVER
TUXEDNI BAY
CLAM GULCH
NINILCHIK
COOK INLET
CHINITNA BAY
ANCHOR POINT
UPPER COOK INLET SUBSISTENCE GILL NET AND DIP NET FISHING AREAS
US Army Corps of Engineers Alaska District
COOK INLET NAVIGATION
EA-2

cranes. The Susitna Flats salt marsh reaches peak densities in early May, with as many as 100,000 waterfowl using the flats to feed, rest, and mate before nesting. This refuge also hosts several thousand lesser sandhill cranes. More than 8,000 swans and about 10,000 ducks nest in the Susitna Flats. Shorebirds are the first birds to migrate through the area in the fall. Dabbling and diving ducks, swans, and geese begin arriving in late August. Their numbers peak by early October before they move on a few weeks later.

The coastal marshes are recognized as important resting and staging areas for water birds during spring and fall migration. The marshes are also important breeding habitat. These marshes provide hunting and other recreational opportunities in Alaska's most heavily populated area.

Bird distribution in the Point Woronzof/Knik Arm area may be largely determined by the availability of food. Shorebirds were found in greatest numbers where there were clams and gammarid amphipods, as well as a rich algal cover. An unvegetated mudflat zone above the algal zone contains almost no macroscopic life. The ducks feed on the mudflat algae. The alkali-grass is inhabited by abundant insects. The creeping alkali-grass is probably consumed by snow geese and Canada geese during their spring migration. Seaside arrow-grass and other plants provide shelter and possibly food for waterfowl in the uppermost third of the marsh. Stickleback inhabit waters in the upper reaches of large tidal channels. Mew, glaucous-winged, and Bonaparte's gulls, and arctic terns may feed on them (Quimby 1972).

A subspecies of the peregrine falcon *Falco peregrinus anatum* is listed as endangered by the U.S. Fish and Wildlife Service and may pass over the Anchorage area during migration to and from nesting areas further north. Another subspecies, *F. peregrinus peales*, is known to nest in coastal areas of Southcentral Alaska but is not listed as endangered or threatened.

3.2.4 Marine Mammals. Although 23 species of marine mammals are present in Southcentral Alaskan waters, only a few reach upper Cook Inlet north of the forelands. Cook Inlet supports an apparently distinct population of 300 to 400 beluga whales. Belugas have been seen regularly in Cook Inlet from March through November. Seasonal concentrations occur in the upper inlet during late May and June. Reasons for these concentrations are not fully understood; however, beluga stocks commonly concentrate near river mouths in the spring. Belugas may be attracted to the warm, coastal near-shore water for molting and to benefit the newborn calves. Calving areas have not been documented in Cook Inlet. Availability of important food sources may also cause near-shore or river mouth concentrations. The arrival of belugas in the northern part of Cook Inlet coincides with large runs of adult and smolt salmon and eulachon. Belugas feed in the upper 100 meters of the water column and are known to consume at least 100 different species of fish and invertebrates in other parts of their range. Smelt, capelin, herring, and various species of cod are common in their diet (National Marine Fisheries Service 1992).

Harbor seals inhabit Augustine and Shaw Islands and occur on the entire west side of Cook Inlet, with a concentration at the mouth of the Susitna River (Evans *et al.* 1972). Killer and minke whales have been observed in the upper inlet. Harbor porpoise also have been observed in Turnagain Arm and at the mouths of rivers chasing eulachon. Steller's sea lions have been observed but are rare (personal communication, Brad Smith, National Marine Fisheries Service 1992).

4.0 ENVIRONMENTAL CONSEQUENCES

4.1 No Action

The no-action alternative would leave the shoal in its present condition, having no effect on the natural environment. Shipping to the port of Anchorage would continue to be dependent on tides for efficient passage.

4.2 Knik Arm Shoal Dredging

The Knik Arm Channel would require dredging 848,600 cubic meters (1,109,918 cubic yards) of primarily poorly graded sand, gravel, and boulders with a small percentage of silty sand/clay to the required depth of -13.5 meters (-44 feet) Mean Lower Low Water. A deep open-water site near Fire Island is proposed for dredged material disposal. The disposal site conditions are believed to be similar to the dredged material, consisting of poorly graded sand and silty sand. Maintenance dredging would be required to maintain project depth to -12 meters MLLW. Maintenance dredging is anticipated every 5 years, resulting in 398,000 cubic meters (520,560 cubic yards) of material. The dredging and disposal impact evaluation under Section 404(b)(1) of the Clean Water Act is contained in EA appendix 1.

4.2.1 Physical Impacts. Suspended sediment load could increase in the water column during dredging and disposal. Background levels of suspended sediment are so high that the potential increases in suspended material or turbidity do not appear significant. No turbidity plume can be seen during Anchorage harbor dredging and barge dumping of fine silt.

Other water quality parameters, including dissolved oxygen, temperature, and salinity, should not be significantly affected. The dredged material would be loaded onto a barge with a capacity of 2,300 cubic meters. An estimated three barge loading and dumping trips per day over a 90-day period would be required. Barge dumping would take approximately 30 minutes to complete. The material would quickly fall en masse to the sea floor. A significant plume would not be measurable in the turbid water. The disposal site is a deep-water area between two current ridges. The dredged material would be carried by currents along existing seabed contours parallel to Fire Island. Dredged material would not be deposited onto Fire Island beaches.

The shoal is in an area of strong currents, where constant scour of seabed materials occurs. Dredging of the shoal would tend to increase the scour potential, reducing the need for maintenance dredging.

The likelihood of contamination by this material within the water column and sea floor is acceptably low and has been excluded from further evaluation procedures (testing) under Section 404 of the Clean Water Act based on:

1. The dredged material is not a carrier of contaminants and is removed from contaminant sources. The sediments have not been disturbed since the ice age.

2. The discharge site is adjacent to the excavation site and subject to the same sources of contaminants, if any, and materials at the two sites are substantially similar.

3. The dredged material is composed primarily of sand, gravel, and/or inert materials.

4. The dredging and disposal sites are in a high-energy environment where currents and tidal fluctuations are high.

4.2.2 Biota. Project impacts to benthic fauna would be minimal because of the low biological productivity of the Knik Arm sea bottom. The severe estuarine environment supports low numbers and varieties of benthic and epibenthic organisms. The redistribution of sea bottom material from one area to another should have little effect on an already depressed biological community. Increases in turbidity during the dredging and disposal should not affect anadromous fish, either at the juvenile or adult life stages, because of the existing high sediment concentrations in the water column. The dredging and disposal operation would deter fish from the project site. This avoidance behavior should not significantly affect their migration or other biological requirements.

Project effects to beluga whales would be minimal. The whales would hear the vibrations of the heavy equipment and be deterred from the immediate area. The diesel engines of the crane and tug boats are estimated at 400 hertz, which is equivalent to the engine noise from ships that commonly use the shipping lanes.

The incidence of marine birds in the area is too low for the project to have a significant effect.

The channel's distance from shore should keep the activities from disturbing the various salt marshes, which have the greatest productivity.

No threatened or endangered species or cultural resources would be affected by the Knik Arm shoal dredging project.

4.2.3 Socioeconomic. The dredging and disposal activities, which are estimated to take several months, are not likely to disrupt shipping or commercial fishing openings. Discussions with the Northern District Setnetters Association indicated that they were concerned that disposal activities near Fire Island would deter fish from their nets. However, this is not expected to occur. The disposal activity would occur 3 times per day, at most, and last approximately 30 minutes each time. The dredged material would quickly drop to the bottom, causing little additional turbidity or noise.

5. REQUIRED COORDINATION

5.1 Public Involvement Program

A notice was sent to Federal, State and private interested parties describing the project. The purpose was to identify issues and generate comments. A State of Alaska Division of Governmental Coordination scoping review was conducted. Coordination letters are contained in EA appendix 3.

5.2 Coordination With Agencies

A Section 404(b)(1) evaluation under the Clean Water Act, which discusses discharge of dredged or fill material, has been prepared for the selected plan and is in EA appendix 1. A State of Alaska Certificate of Reasonable Assurance under Section 401 of the Clean Water Act would be issued when the State concludes its coastal zone management program review.

This project has no potential to affect cultural resources; therefore, coordination with the State Historic Preservation Officer was not necessary.

Endangered Species Act coordination correspondence is contained in EA appendix 3 and in the letter modifying the USFWS Coordination Act Report in EA appendix 2. The project would have no effects on threatened or endangered species.

Information on this project was forwarded to the Environmental Protection Agency's Region 10, which had no preliminary comments.

5.2.1 U.S. Fish and Wildlife Service.

The U.S. Fish and Wildlife Service (USFWS) submitted a report required by the Fish and Wildlife Coordination Act. Under provisions of the Act, the USFWS describes significant resources in the vicinity of the proposed water resources project, identifies potential project impacts, and makes recommendations for avoiding or mitigating project impacts.

Project dredging modifications and the need for maintenance dredging were determined after the USFWS report submittal. The views of the USFWS are reflected in the agency's letter to Col. Peter A. Topp, which is included in EA appendix 2. Dredging depths and quantities were further defined subsequent to this letter. The Coordination Act Report and amendment letter are in EA appendix 2.

USFWS Recommendations in Coordination Act Report.

a. If practicable, scheduling dredging operations to begin after June to avoid the spring smolt migration should eliminate impacts to virtually all juvenile salmonids.

b. The North Cook Inlet Setnetters Association should be contacted to determine if they would like to meet with the Corps to discuss impacts of the project on commercial fishing.

Response from Alaska District, Corps of Engineers.

a. Consideration will be given to scheduling work after June if practicable.

b. Project scenarios have been discussed with Mr. Steve Burand of the Northern District Setnetters Association.

5.2.2 Alaska Coastal Management Program (ACMP).

Coordination and review under the State Coastal Zone Management Program will be conducted with the circulation of the Environmental Assessment.

The proposed dredging project in Cook Inlet would be undertaken in a manner consistent to the maximum extent practicable with the ACMP. This determination is based upon the description of the proposed project and its effect, and upon an evaluation of the relevant provisions of the management program.

Pertinent Federal and State laws and statutes have been reviewed for the proposed project. Consultation correspondence is in EA appendix 3.

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ENVIRONMENTAL ASSESSMENT
APPENDIX 1

COOK INLET DEEP-DRAFT NAVIGATION
SECTION 404 (b)(1) EVALUATION

EVALUATION UNDER SECTION 404(b)(1), CLEAN WATER ACT

Cook Inlet Deep Draft Navigation, Alaska
Dredging Knik Arm Shoal

I. PROJECT DESCRIPTION

A. General Description

A deep-draft shipping channel is proposed through Knik Arm Shoal to provide greater access at all tidal ranges to the Port of Anchorage. The proposed channel is 305 meters (1,001 feet) wide and 2,000 meters (6,582 feet) long. These dimensions were developed through intensive economic optimization. The channel allows for only one lane of traffic and would be safe in the worst of icy winter conditions. Initial dredging would be to -13.0 meters (-42.6 feet) at 0 Mean Lower Low Water (MLLW), which is the design draft required by a deep-draft vessel. The initial dredging quantity is estimated at 848,600 cubic meters (1,109,918 cubic yards). Maintenance dredging of 397,600 cubic meters (520,037 cubic yards) of material is anticipated every 5 years.

The proposed dredged material disposal site is a deeper water area near Fire Island. The majority of the dredged material is sand and gravel with some boulders. The disposal site has similar substrate. The initial channel dredging is expected to take 3 months during the ice-free period. The dredging method would be by mechanical clamshell dredge, which would deposit the dredged material onto a dump-scow barge.

B. Description of Dredged and Fill Material

A marine geophysical survey using precision navigation and echo sounding, sub-bottom profiling, and continuous seismic reflection profiling was undertaken to determine the bottom and sub-bottom conditions of the Knik Arm Shoal area in Cook Inlet. In addition, core sampling and grab surface samples were collected to determine precise sediment particle sizes.

The geophysical study indicated that surficial and subsurface sediments are glaciofluvial deposits composed of sand and gravel with some cobbles and boulders less than 0.5 meters in diameter. There appear to be pockets of fine-grained sediments.

Core sampling was conducted to determine precise sediment particle sizes, formation type, and depth. This information is detailed in the geotechnical reports. In summary, the crest of the shoal is 7 to 8 meters below sea level and has 4 to 5 meters of relief above the surrounding sea floor. The glaciofluvial deposits are composed of sand and gravel with some cobbles and boulders less than 0.5 meters in diameter. The pockets of fine-grained sediments appear to be outside the proposed dredged channel.

Seven of the eight grab samples were classified as poorly graded sand, and one sample was poorly graded gravel with sand.

The area to be dredged and the disposal site have a similar sandy gravel sea bottom habitat. Biota in these areas are sparse due to the high-energy environment. Biota in Cook Inlet are generally limited because the high silt load in the water reduces light penetration.

C. Description of the Proposed Discharge Site

The disposal site is an adjacent open-water area with similar substrate characteristics as the dredged material described above.

II. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations

The sand and gravel to be dredged is characteristic of material found in high-energy environments. Few benthos are within this habitat. Minimal turbidity would result from dredging and disposing of this coarse-grained material. The effect to the water column would be negligible because of the already high silt content of the water. The dredging and disposal activity would temporarily deter seasonally migrating salmon and other demersal fish and marine mammals from the area.

B. Water Circulation, Fluctuation, and Salinity Determinations

The proposed dredging and disposal would not adversely affect water fluctuations, salinity, or circulation in the area. The dredge and disposal sites are in areas with strong currents and high scour conditions.

C. Suspended Particulate/Turbidity Determinations

The coarse-grained material would have minimal effects on the water column. The material would drop out of the barge in one mass, quickly reaching the bottom. Tidal/current action would scour the material quickly with little effect. Dissolved oxygen would be slightly depleted due to absorption of oxygen molecules into silt particles or oxygen uptake by organic acids. Research has shown that oxygen depletion related to disposal of dredged material is a temporary occurrence, with the oxygen level usually returning to normal shortly after completion of the operation.

D. Contaminant Determinations

The fill material is not associated with any pollutants or toxicants, either natural or man-induced. The project site is in an extremely high-energy environment, and there are no known sources of pollutants in the area. The sediments are predominantly coarse-grained and have little retention capacity for contaminants. The likelihood of contamination by this material is low, and exclusion from further evaluation procedures is based upon:

1. The dredged material is not a carrier of contaminants.

2. The discharge site is adjacent to the excavation site and subject to the same sources of contaminants, and materials at the two sites are substantially similar.

3. The dredged material is composed primarily of sand, gravel and/or inert materials.

This material is suitable for open-water disposal and meets the criteria of testing as defined in the Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual (Draft), Section 4.0, and is relevant to Guidelines 40 CFR 230.61 (a) (b) (c). Because of the listed reasons, a Tier II exclusion has been invoked. In adherence to the prescribed procedures of the Testing Manual cited above, further testing has been deemed unnecessary and inappropriate.

E. Aquatic Ecosystem and Organism Determination

A slight increase in suspended sediments and turbidity could impact plankton populations in the immediate project area. The impacts would be temporary and minor.

Free-swimming organisms would avoid the immediate area near the fill site due to the decrease in dissolved oxygen, increased agitation, and other disturbances to the substrate and water column. Most of these organisms would be able to avoid the area during the project. Impacts to the aquatic food web would be insignificant.

The proposed action would have no effect on threatened or endangered species.

F. Proposed Disposal Site Determinations

Dredging and disposal would take place in open water in a high-energy environment. Mixing zones are not necessary because of the type of material and the high sediment load of the ambient water.

The proposed action would comply with applicable water quality standards and would have no detrimental effects on any of the following:

1. Municipal and private water supplies;

2. Recreational and commercial fisheries;

3. Water-related recreation; or

4. Esthetics.

The dredging project would have only a temporary effect on the water column. Recreational and commercial fisheries would not be negatively affected by the dredging. No parks, national or historical monuments, cultural resources, national seashores, wilderness areas, research sites, or similar preserves are located in the area.

G. Determination of Cumulative Effects on the Aquatic Ecosystem

There would be no cumulative effects due to the dredging and disposal.

H. Determination of Secondary Effects on the Aquatic Ecosystem

No significant secondary impacts are expected to result from the dredging and disposal.

III. FINDING OF COMPLIANCE OR NONCOMPLIANCE WITH THE RESTRICTIONS ON DISCHARGE

A. Adoption of the Section 404(b)(1) Guidelines

The proposed project complies with the requirements set forth in the Environmental Protection Agency's guidelines for specification of discharge sites for dredged or fill material.

B. Evaluation of Availability of Practicable Alternatives

A environmental assessment was prepared in conjunction with the dredging project. A discussion of the alternatives is confined to optimized dredging depths and the no-action alternative. Other practical alternatives would require at least as much dredging and would produce similar impacts. The open-water disposal site is the most practical option for disposal of the large amount of dredged material. There were no practical upland disposal sites.

C. Compliance with Applicable State Water Quality Standards

The project complies with State water quality standards.

D. Compliance with Applicable Toxic Effluent Standards or Prohibition under Section 307 of the Clean Water Act

The proposed project complies with the toxic effluent standards of Section 307 of the Clean Water Act.

E. Compliance with the Endangered Species Act of 1973

The proposed project complies with the Endangered Species Act.

F. Compliance with Specified Protection Measures for Marine Sanctuaries Designated by the Marine Protection, Research and Sanctuaries Act of 1972

The proposed project complies with the Marine Protection, Research and Sanctuaries Act of 1972.

G. Evaluation of Extent of Degradation of the Waters of the United States

There would be no effect to municipal and private water supplies. Recreation and commercial interests would not be negatively affected by the dredging and disposal project. There would be no significant adverse impacts to plankton, fish, shellfish, wildlife, and/or special aquatic sites caused by this project.

The dredging and disposal aspects of this project would cause no significant adverse effects on aquatic life and/or other wildlife dependent on aquatic ecosystems.

H. Appropriate and Practicable Steps Taken To Minimize Potential Adverse Impacts of the Discharge on the Aquatic Ecosystem

All appropriate and practicable steps would be taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem.

On the basis of the guidelines, the proposed dredging and disposal is specified as complying with the requirements of these guidelines.

ENVIRONMENTAL ASSESSMENT
APPENDIX 2

COOK INLET DEEP-DRAFT NAVIGATION
U.S. FISH AND WILDLIFE SERVICE
COORDINATION ACT REPORT

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services Anchorage
605 West 4th Avenue, Room 62
Anchorage, Alaska 99501

IN REPLY REFER TO: WAES

Colonel Peter A. Topp
District Engineer, Alaska District
U.S. Army Corps of Engineers
Post Office Box 898
Anchorage, Alaska 99501

Dear Colonel Topp:

This letter modifies the U.S. Fish and Wildlife Service's draft Fish and Wildlife Coordination Act (FWCA) Report on the U.S. Army Corps of Engineers' (Corps) Cook Inlet Navigation Study near Anchorage, Alaska dated August 1995. The information contained in this letter combined with our August 1995, draft report will comprise our final FWCA report on the project.

We have reviewed the changes to the project included in Mr. Guy McConnell's letter dated December 4, 1995. Specifically, the dredged channel width would be increased from 220 meters to 305 meters and the dredging quantities would be increased from 765,725 m^3 to 1,116,100 m^3. Maintenace dredging would occur once every 5 years, and quantities of dredged material would not exceed 350,000 m^3. Maintenance dredged materials would be comprised of course sands and gravels.

These changes in project features would not alter the conclusions discussed in our draft FWCA Report. The proposed project is expected to have very minor impacts upon the fish and wildlife resources of upper Cook Inlet. We would continue to recommend that, if practicable, dredging should be scheduled to begin after June to avoid the spring salmon smolt outmigration.

Ms. Lizette Boyer of your Environmental Resources Section Staff requested that we include in this letter information on threatened and endangered species since they were not discussed in our draft FWCA report. The endangered American peregrine falcon (*Falco peregrinus anatum*) may be present flying over the project site during the spring and fall migration. Their presence in the project area would be transitory and irregular. It is anticipated that the project would not affect the peregrine falcon. The threatened Steller sea lion (*Eumetopias jubatus*) could occur in the project vicinity; however, the project site is out of its usual range and its occurance would be considered rare. The National Marine Fisheries Service should be contacted for further coordination on the Steller sea lion.

Our draft FWCA report stated that harbor seals (*Phoca vitulina*) are uncommon or rare in upper Cook Inlet. More recent information indicates that there is a small group of harbor seals (up to 25) that regularly occurs near the mouth of the Susitna and/or Little Susitna Rivers. The project is not expected to affect this group of marine mammals.

This document is prepared in accordance with the Fiscal Year 1994 scope of work and the FWCA [PL 85-624 Section 2(b)], and is being provided for equal consideration of fish and wildlife conservation with other project purposes.

For additional coordination on this project, please contact our project biologist Gary Wheeler at 271-2780.

Sincerely,

Ann G. Rappoport

Ann G. Rappoport
Field Supervisor

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Anchorage Field Office
Ecological Services and Endangered Species
605 West 4th Avenue, Room 62
Anchorage, Alaska 99501

IN REPLY REFER TO:
WAES

Colonel Peter A. Topp
District Engineer, Alaska District
U.S. Army Corps of Engineers
Post Office Box 898
Anchorage, Alaska 99501

AUG 11 1995

Dear Colonel Topp:

Enclosed is the U.S. Fish and Wildlife Service's draft Fish and Wildlife Coordination Act (FWCA) Report on the U.S. Army Corps of Engineers' (Corps) Cook Inlet Navigation Study near Anchorage, Alaska. The document was prepared in accordance with the Fiscal Year 1994 scope of work and the FWCA [PL 85-624 Section 2(b)], and is being provided for equal consideration of fish and wildlife conservation with other project purposes.

Findings herein are based on information provided by Corps' project biologist Lizette Boyer. Biological information is based on literature review and coordination with the Corps, National Marine Fisheries Service, and the Alaska Department of Fish and Game.

Sincerely,

Ann G. Rappoport
Field Supervisor

Enclosure

Draft Coordination Act Report

for

Cook Inlet Navigation Study

Prepared by:

Gary P. Wheeler
Ecological Services Anchorage

U.S. Fish and Wildlife Service
Alaska Region
Anchorage, Alaska
August 1995

COOK INLET NAVIGATION STUDY
FISH AND WILDLIFE COORDINATION ACT REPORT

INTRODUCTION

This report constitutes the U.S. Fish and Wildlife Service's draft Fish and Wildlife Coordination Act (FWCA) Report for the U.S. Army Corps of Engineers' (Corps) Cook Inlet Navigation Study near Anchorage, Alaska. The document was prepared in accordance with the Fiscal Year 1994 scope of work and the FWCA [PL 85-624 Section 2(b)], and is being provided for equal consideration of fish and wildlife conservation with other project purposes.

Service involvement in the project includes evaluating the potential impacts of the project on fish and wildlife resources and their habitats and recommending methods for mitigating adverse impacts and/or enhancing these resources, where practicable.

Findings herein are based on information provided by Corps' project biologist Lizette Boyer. Biological information are based on literature review and coordination with the Corps, National Marine Fisheries Service, and the Alaska Department of Fish and Game.

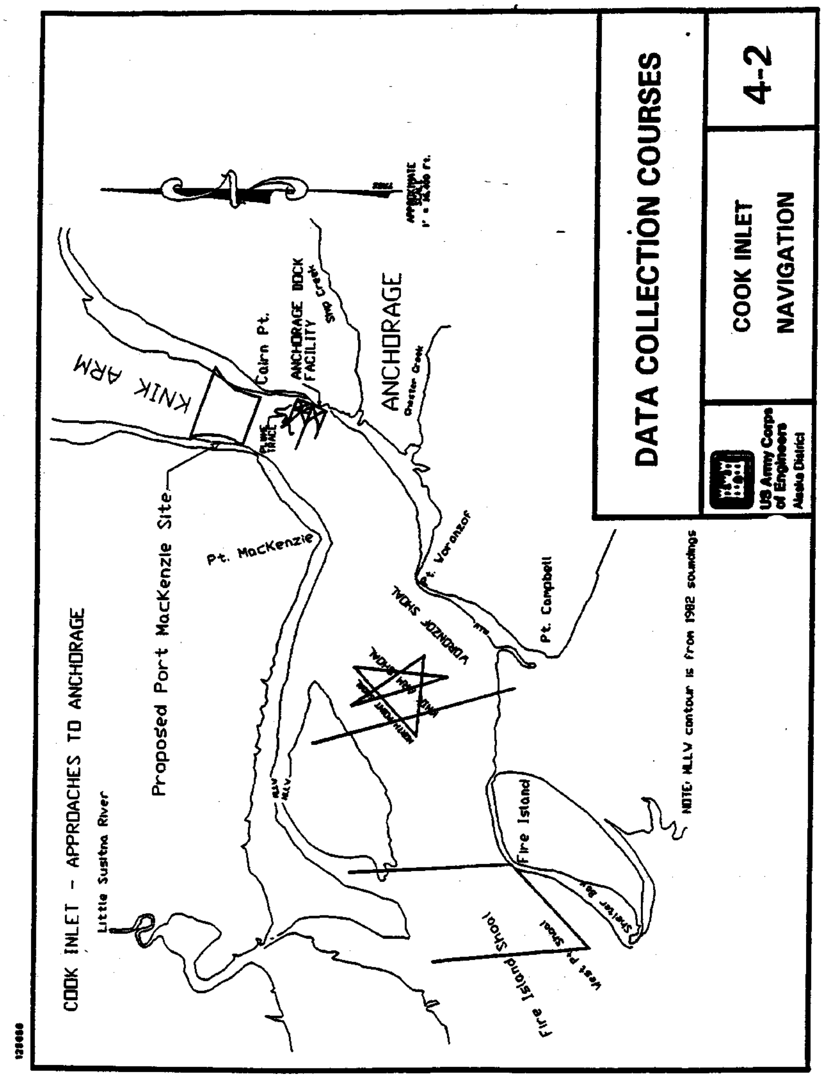
STUDY AREA

The study area encompasses northern Cook Inlet in the vicinity of Anchorage, Alaska (Figure 1). Cook Inlet is a large estuary in southcentral Alaska. Nearly half of Alaska's population lives in close proximity to the Inlet. Anchorage, the State's largest city and center of commerce, transportation, recreation, and industry, is located at the Inlet's northeast end, between Knik and Turnagain Arms.

Northern Cook Inlet is a shallow basin, with depths generally less than 100 feet (30.5 m). Numerous freshwater rivers mix with and dilute incoming Gulf of Alaska sea water, contributing valuable nutrients as they deliver large amounts of sediment to Cook Inlet. The majority of fresh water enters the northern inlet from three glacier-fed rivers at its northern end. These rivers, the Matanuska, Susitna, and Knik, contribute nearly 70 percent of the fresh water entering the inlet (Gatto 1976). Upper inlet tributaries also annually discharge 75 million tons (68 million metric tons) of sediment into the inlet (Knott 1986, Alaska District Hydraulics and Waterways Section 1986).

Cook Inlet has the second highest tides in all of the Americas (Anthony and Tunley 1976). Mean daily tidal range is approximately 29.5 feet (9.0 m) in Anchorage. Large tidal fluctuations result in rapid currents, in excess of 11 feet per second (3.4 m/sec) (Britch 1976). The currents and resulting turbulence produce high levels of suspended sediment [values to 1,350 mg/l are reported (Kinney et al. 1968)].

Ice is another environmental factor in Cook Inlet. Sea ice can exist in the inlet as floes greater than 1,000 feet (305 m) wide and up to 3 feet (0.9 m) thick. Pressure ridges up to 18 feet (5.5 m) sometimes form as these floes


DATA COLLECTION COURSES
COOK INLET
NAVIGATION
4-2
US Army Corps of Engineers
Alaska District
COOK INLET - APPROACHES TO ANCHORAGE
Little Susitna River
Proposed Port MacKenzie Site
Pt. MacKenzie
KNIK ARM
Cairn Pt.
ANCHORAGE DOCK FACILITY
Ship Creek
ANCHORAGE
Chester Creek
Pt. Woronzof
Pt. Campbell
WORONZOF SHOAL
Fire Island
Shelter Bay
West Pt. Shoal
Fire Island Shoal
NOTE: MLLV contour is from 1982 soundings

collide (Gatto 1976). Beach ice quickly forms on tidal flats as seawater contacts frozen tidal mud. Beach ice often deposits in layers on the mudflats during high tides. Estuary or river ice is often discharged into the inlet during spring breakup (LaBelle et al. 1983). Ice can be a navigational hazard for up to 5 months during the year. Ice begins forming in October and by December covers about half the water surface in the northern portion of the inlet. Most ice has melted by late March or early April (Gatto 1976).

FISH AND WILDLIFE RESOURCES

Upper Cook Inlet exhibits one of the most extreme physical habitats in the world. The combination of extreme tides and turbidity, strong currents, and mobile bottom sediments has led biologists to surmise that, except for seasonal passage of anadromous fish occasionally pursued by beluga whales, the upper inlet is very unproductive (Bakus et al. 1979).

Marine Flora and Invertebrates

Cold temperatures and glacial silt limit primary productivity in the waters of upper Cook Inlet. Plankton are scarce thus limiting marine food webs. Diatoms are the most common phytoplankton in upper Cook Inlet. Dominant genera in Knik Arm include *Coscinodiscus*, *Actinoptychus*, *Pleurosigma*, *Rhizosolenia*, and *Melosira* (Kinney et al. 1970). In Turnagain Arm, Naviculoid diatoms appear dominant (Jackson 1970). The most common zooplankton in upper Cook Inlet include copepods, cyclopods, and harpacticoids (Bakus et al. 1979).

Macro algae species known to occur in the upper Cook Inlet region include *Fucus*, *Cladophora*, *Vaucheria* and *Enteromorpha* (Jackson 1970); however, the only benthic algae found between Point Woronzof and Point Campbell, was *Vaucheria longicaulis* (Bakus et al. 1979).

Subtidal benthic organisms are sparse in upper Cook Inlet. Intertidal invertebrates found in upper Cook Inlet sediments include *Macoma balthica*, *Mya arenaria*, and *Clinocardium nuttalli* (Bakus et al. 1979). *Littorina* is found in the Turnagain Arm area (ADFG 1977). Invertebrates observed within or near the Anchorage Coastal Wildlife Refuge include mysids and gammarid amphipods, minute hydroids, harpacticoid copepods, crangonid shrimp, and five species of polychaetes (Bakus et al. 1979).

Fish

No resident fish are known to occur in the vicinity of the Knik Arm Shoal; however, transient individuals would likely include the following species taken in nearby Knik Arm: chinook (*Onchorhynchus tshawytcha*), coho (*O. kisutch*), sockeye (*O. nerka*), chum (*O. keta*), and pink (*O. gorbuscha*) salmon; humpback whitefish (*Coregonus pidschian*); Bering cisco (*C. laurettae*); longfin smelt (*Spirinchus thaleichthys*); eulachon (*Thaleichthys pacificus*); Saffron cod (*Eleginus gracilis*); threespine stickleback (*Gasterosteus aculeatus*); Pacific tom cod (*Microgadus proximus*); lemon or English sole (*Parophrys vetulus*); Dolly varden (*Salvelinus malma*); rainbow trout (*Salmo gairdneri*); Pacific herring (*Clupea harengus*); ringtail snailfish (*Liparis rutteri*); Starry flounder (*Platichthys stellatus*); yellowfin sole (*Limanda aspera*), ninespine stickleback (*Pungitius pungitius*), and Pacific staghorn sculpin (*Leptocottus armatus*) (Dames and Moore 1983).

Chum salmon fry appear to be present in Knik Arm in significant numbers from mid-May through at least mid-June and perhaps into July. Residence time in Knik Arm and probably upper Cook Inlet is brief (Dames and Moore 1983). Returning adults peak during the third week of July (Bakus et al. 1979).

Coho juveniles are present in Knik Arm from about May 20 until at least mid-June with a peak abundance probably occurring in early June. (Chlupach 1982, Dames and Moore 1983). Residence time in upper Cook Inlet appears brief. Returning adults peak during July 18-24 (Bakus et al. 1979).

Juvenile sockeye salmon migrate from area streams at a time similar to cohos although the peak of abundance may be later and the run may taper off more slowly (Chlupach 1982). Returning adult migrants peak during the second and third weeks of July (Bakus et al. 1979).

Chinook salmon juveniles migrate from area streams at about the same time as other juvenile salmon. During test netting in Knik Arm, more than half the juvenile chinook that had food in their stomachs contained items of saltwater origin. This indicates chinook may more effectively exploit the resources of Knik Arm than other salmon species and therefore spend more time there. Returning adults peak during mid-June (Bakus et al. 1979).

Pink salmon juveniles migrate from north Cook Inlet streams in late May with a peak during June (Roth et al. 1986). Returning adult runs peak during July 12-17 and July 26-August 6 (Bakus et al. 1979).

Eulachon and threespine stickleback are both anadromous species. It is believed that threespine stickleback are residents as well as migrants in Knik Arm. It is not known whether eulachon reside in Knik Arm during periods other than during the spawning migration (April-May) (Dames and Moore 1983).

Dames and Moore (1983) found Saffron cod and Bering cisco to be relatively abundant and surmised that they were well adapted to survival in the Knik Arm environment during at least part of the year. Little is known of the life history of anadromous populations. Bering cisco presumably spawn in the fall in area streams and may reside in the Upper Inlet estuary for the remainder of the year. Saffron cod inhabit coastal areas and are known to tolerate low salinity (Blackburn 1978, Morrow 1980). Adult cod move into deep water in the summer and return to shallow areas influenced by tidal currents in the winter to spawn (Andriyashev 1954 cited by Blackburn 1978). The cod and cisco as well as other species such a snailfish and longfin smelt are able to feed effectively in the turbid Knik Arm environment.

Marine Mammals

The beluga whale (*Delphinapterus leucas*) population in Cook Inlet is thought to be geographically and reproductively isolated from other beluga whale populations (Morris 1988). Whales concentrate at river mouths from late May through June and disperse throughout middle and upper Cook Inlet during July and August. They depart upper Cook Inlet in November (Morris 1988). The return of belugas to upper Cook Inlet coincides with large spawning runs of eulachon in the lower Susitna River in late May and early June. Several hundred belugas have been observed near Point Woronzof during summer months (Bakus et al. 1979). The Cook Inlet population has been estimated at 200 to 500 individuals (Hazard 1988). Available data suggest the population has remained stable over the past 20 to 30 years (Frost and Lowry 1990).

Food habits of Cook Inlet belugas are not well known, but they are believed to feed on salmon, eulachon, and tom cod. Belugas in other areas are known to consume at least 100 different fish and invertebrate species (NMFS 1992).

Calving occurs during late spring and early summer in coastal areas where belugas congregate, particularly in estuaries. Calving areas in Cook Inlet have not been documented, but Calkins (1983) hypothesized that calving begins between mid-June and mid-July in the large estuaries of the upper Inlet.

Natural mortality could include entrapment in sea ice, stranding at low tide, and predation by killer whales. Killer whales are known to attack beluga whales on occasion (Burns and Seaman 1985), and are their only known predator in Cook Inlet. Sergeant and Brodie (1969) hypothesized that beluga distribution is influenced by killer whale distribution. During the summer of 1994, a large pod of belugas (over 100 individuals) were stranded at low tide near the mouth of the Susitna River. It was speculated at the time the belugas had sought refuge from killer whales in shallow water. The extent of predation by killer whales is unknown (NMFS 1992).

Native harvest of Cook Inlet beluga whales has varied from 7 to 12 whales in recent years. All landings reported have been from near the Susitna River drainage (NMFS 1992).

Other marine mammals [killer whales (*Orcinus orca*), gray whales (*Eschrichtius robustus*), harbor seals (*Phoca vitulina*) and Steller sea lions (*Eumetopias jubatus*)] are uncommon or rare in upper Cook Inlet (Bakus et al. 1979).

<u>Birds</u>

The following water birds have been observed in the area and may occur near the project site: glaucous-winged gull (*Larus glaucescens*), herring gull (*Larus argentatus*), mew gull (*Larus canus*), Bonaparte's gull (*Larus philadelphia*), red-necked phalarope (*Phalaropus lobatus*), and arctic tern (*Sterna paradisaea*). Birds are uncommon on the water surface in the upper inlet except for occasionally resting or feeding in areas where debris has been concentrated.

PROJECT DESCRIPTION

Deep draft vessels suffer tidal delays approaching and departing the Port of Anchorage. Pilots of ships traveling to or from Anchorage have for decades crossed Knik Arm and Fire Island Shoals on high water by slowing their ships in lower Cook Inlet on approach or waiting at the dock on departure. Delays occur in two forms: (1) extra time spent approaching Anchorage slowly in order to cross the shoals at high tide, and (2) time spent at the dock ready for departure waiting for high tide at the shoals.

Knik Arm Shoal has a controlling depth of 25 feet (7.6 m) at low tide and is responsible for all delays. A computer simulation study indicated that dredging a channel across Knik Arm Shoal at a depth of -35 feet (-10.7 m) MLLW would reduce shipping delays an average per transit of 2.5 hours for Sea-Land vessels and 3.1 hours for TOTE vessels (U.S. Army Corps of Engineers 1993).

Studies have been conducted to optimize channel depth and width. The results indicate that a channel depth of -44.3 feet (-13.5 m) and width of 720 feet (220 m) should be optimum. Channel depth is expected to stabilize over time at -39.4 feet (-12.0 m). Approximately 765,725 m^3 of substrate would be dredged to construct a channel of the above dimensions. It is projected that no maintenance dredging would be required (personal communication, O. Smith, U.S. Army Corps of Engineers, 1995).

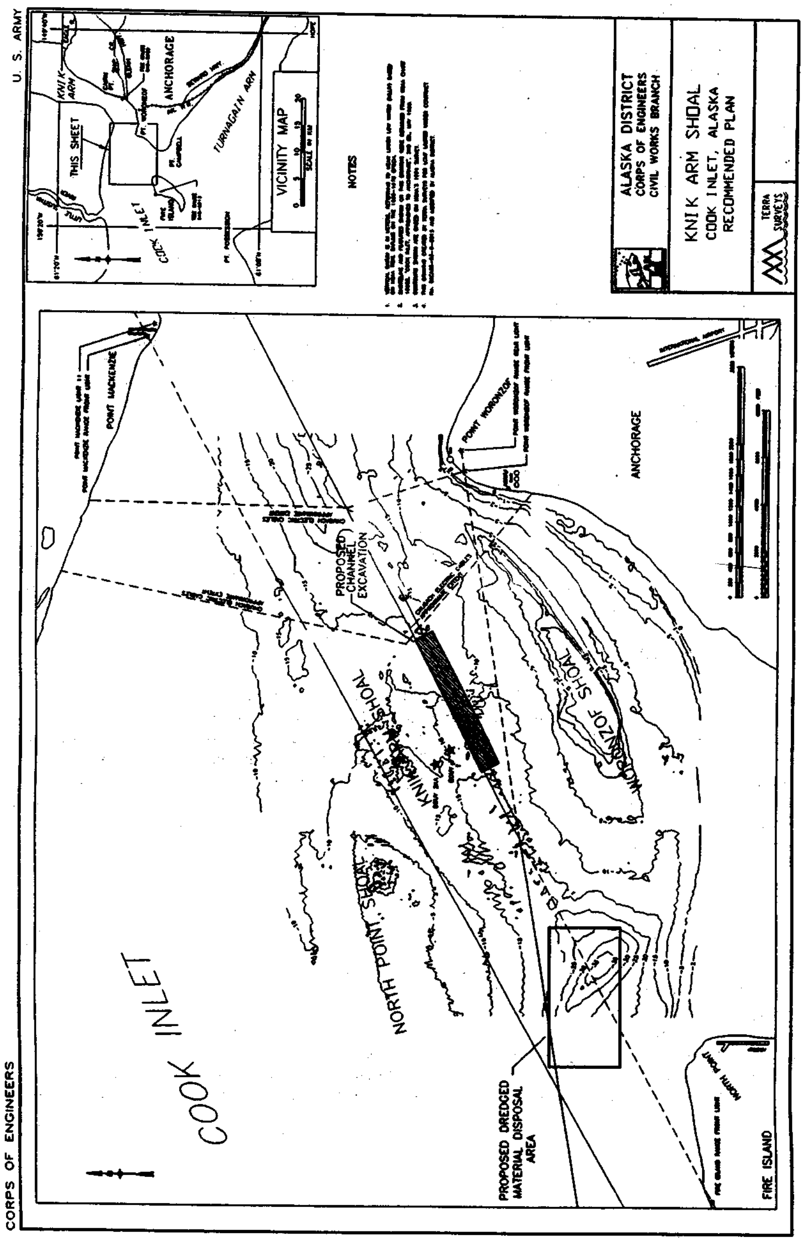
An area deemed suitable for open-water disposal of dredged material lies north and east of North Point on Fire Island in depths exceeding 60 feet (18.3 m). Material dredged for this project would be disposed at this site (Figure 2). The southwest corner of the site would be located where 150° 10′ W. longitude intersects the -60-foot (-18.3-meter) MLLW bottom contour. The site would extend 0.5 NM (1.0 km) north and 1 NM (1.9 km) east of this point. It is expected that dredged sediments will accumulate to a depth of approximately 1.6 feet (0.5 m) at the site. The sediment plume associated with material disposal is expected to dissipate within 10 to 15 minutes of the barge dumping. No sediment is expected to accumulate on the beaches of Fire Island due to the steep sloping topography from the Island to the disposal site (personal communication, O. Smith, U.S. Army Corps of Engineers, 1995).

IMPACTS ON FISH AND WILDLIFE

Most impacts from dredging on fish and wildlife resources are attributed to suspension of sediments in the water column. The magnitude of these effects is determined by the nature and quantity of the material suspended and the site-specific hydrological conditions which affect dispersion (LaSalle 1990).

The type of dredge also influences the turbidity produced. Due to the mixture of sediment grain sizes present at the site, it is anticipated that a clamshell or bucket dredge would be used for this project. The turbidity generated by bucket dredge operations comes from four sources: (1) sediment suspended by the impact and withdrawal of the bucket from the bottom; (2) washing of material from the top and sides of the bucket as it moves through the water column; (3) spillage of sediment-laden water out of the bucket after it breaks the water's surface; and (4) inadvertent spillage of material during barge loading or intentional overflow intended to increase a barge's effective load. Other variables can also affect the quantity of material suspended, including bucket size and type (open or enclosed), volume of sediment dredged per cycle, and hoisting speed (LaSalle 1990).

The spacial extent and duration of suspended material largely depends upon the type of sediment being suspended. A typical bucket dredge operation produces


CORPS OF ENGINEERS
U. S. ARMY
THIS SHEET
ANCHORAGE
KNIK ARM
TURNAGAIN ARM
COOK INLET
VICINITY MAP
NOTES
ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH
KNIK ARM SHOAL
COOK INLET, ALASKA
RECOMMENDED PLAN
TERRA SURVEYS
COOK INLET
NORTH POINT SHOAL
KNIK ARM SHOAL
WORONZOF SHOAL
PROPOSED CHANNEL EXCAVATION
PROPOSED DREDGED MATERIAL DISPOSAL AREA
POINT MACKENZIE
POINT WORONZOF
ANCHORAGE
FIRE ISLAND

a downstream plume extending 300 m at the surface and 500 m near the bottom (La Salle 1990); however, the material dredged at projects where these measurements were taken was reported to be fine grain sands and silts. The material to be dredged for this project is classified as "poorly graded sand" and "poorly graded gravel with sand." Because the grain size at this site is considerably larger, the sediment plume should be smaller.

Maximum suspended sediment concentrations in the surface plume are generally less than 500 mg L^{-1} in the immediate vicinity (100 m) of the dredging operation, decreasing rapidly with distance due to settling and dilution. Average water column concentrations in the same area are generally less than 100mg L^{-1} (LaSalle 1990). The use of enclosed or covered buckets has reduced surface suspended sediment concentrations as much as 56 percent (Hayes et al. 1984); however, bottom concentrations were increased as much as 70 percent due to the effect of a pressure wave which precedes the enclosed bucket as it descends. In contrast to the sediment levels resulting from dredging, currents and turbulence in Cook Inlet naturally produce high levels of suspended sediment. The mean suspended sediment concentration in waters near Anchorage was 1,280 mg/l (Everts and Moore 1976) and values to 1,350 mg/l are reported (Kinney et al. 1970).

Consequently, suspended sediment concentrations resulting from dredging would result in somewhat increased sediment concentrations in the vicinity of the dredging operation. However, this increase is likely to be localized in the vicinity of the dredge site and the disposal site and would probably be less than twice the background level of suspended sediment which is naturally very high. The turbidity plume, being tear drop shaped, would likely affect an area perhaps several tens of yards wide in comparison with a channel width in the area of approximately 5 miles (8 km) [at a elevation 0.0 feet (0.0 m) MLLW]. Consequently, a very low percentage of migrating salmon are likely to contact the turbidity plume.

It is likely that north Cook Inlet salmon are adapted to high levels of suspended sediments in as much as many migrate through miles of glacially-affected streams and the turbid northern inlet before reaching the relatively clear waters of southern Cook Inlet. Consequently, elevated suspended sediment concentrations in the vicinity of the dredge and disposal sites are unlikely to have substantial impacts on Cook Inlet fishery resources. This conclusion is supported by Simenstad (1990) who stated that there are few documented cases of injury to anadromous fish in the Pacific Northwest coming into contact with a sediment plume caused by dredging where sediments were uncontaminated.

Impacts associated with dredge material disposal are expected to be minimal. Impacts from dredge material disposal decrease as the disposal site is moved from estuarine habitat to the continental shelf to the deep ocean because biological productivity decreases while dilution and mixing increase (Pequegnat et al. 1978). Extreme tidal currents at the disposal site ensure that dilution and mixing will be high. The potential impact of disposal material is higher on organisms living on or near the bottom than on organisms in the water column. Results of benthic recovery from a deepwater disposal site in Puget Sound indicated that impacts were greatest on benthic organisms buried deeper than 1.6 feet (0.5 m); effects of the disposal operation were confined to the immediate disposal area; benthic repopulation was by horizontal migration; although the population density had not recovered in the center of the disposal area 9 months after disposal, species diversity was greater; and at 9 months both species density and diversity were greater at the margins of the disposal area than at reference areas (Bingham 1978). Benthic fauna in the northern Inlet and at the disposal site are thought to be scarce; consequently, impacts are not expected to be significant.

The same conclusion can be reached for birds and beluga whales in upper Cook Inlet. The sediment plume associated with the dredging and disposal activities is likely to be extremely small in comparison with the available habitat in the area. Additionally, the dredging plume constitutes only a minor addition of sediment in a system that is naturally highly turbid.

Little information is available on the beluga's tolerance to noise in its environment. Unlike some areas inhabited by belugas in the high arctic where there is little human-produced noise, Cook Inlet contains an abundance of noise. Oil platforms, shipping and tanker traffic, commercial fishing, hunting, and recreational boating contribute noise to the Inlet environment. Cook Inlet belugas have apparently habituated to at least some of these noise sources. Belugas occur seasonally close to the Port of Anchorage, at the mouths of rivers with considerable small boat traffic, in areas of activity near oil platforms and coastal facilities, and around commercial fishing operations (Morris 1988). There are many reports of belugas near oil platforms (Hazard 1988), and females with calves have been reported to pass within 10 meters of active platforms (McCarty 1981). McCarty (1981) and Stewart et al. (1983) reported that belugas seem to be unaffected by a constant noise source, but react by temporarily avoiding areas with sudden noise changes.

Noise from the dredging operation is unlikely to significantly displace beluga whales. The dredging noise is probably most likely akin to noise from an oil platform in that it will be relatively constant and from a rather stationary source. It is anticipated that belugas may avoid the immediate vicinity of the dredging operation, but the wide channel in the area of the project site should allow them to freely pass as they move up or down the Inlet.

RECOMMENDATIONS

1. If practicable, schedule dredging operations to begin after June to avoid the spring smolt migration. This should eliminate impacts to virtually all juvenile salmonids.

2. The North Cook Inlet Setnetters Association should be contacted to determine if they would like to meet with the Corps to discuss impacts of the project on commercial fishing.

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ENVIRONMENTAL ASSESSMENT
APPENDIX 3

COOK INLET DEEP-DRAFT NAVIGATION
CORRESPONDENCE

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
222 West 7th Avenue, Box 43
Anchorage, Alaska 99513-7577

September 27, 1994

Guy McConnell
Chief, Environmental Resources Section
U.S. Army Engineer District, Alaska
P.O. Box 898
Anchorage, Alaska 99506-0898

ATTN: L. Boyer

Dear Mr. McConnell:

Thank you for your letter concerning the proposed dredging of a navigational channel along the southern flank of Knik Arm near Anchorage, Alaska. You request comments on the probable biological effects of this work and information on the presence of Threatened or Endangered species listed under the Endangered Species Act of 1972, as amended.

Present staffing and workloads do not allow us to undertake a thorough analysis of the potential environmental effects of the proposed dredging. However, we have several general observations which may be of use in scoping for necessary environmental documentation, including the Fish and Wildlife Coordination Act Report and NEPA statements . The waters of upper Knik Arm are important migratory corridors for anadromous fish. Any extensive dredging should consider the consequence to out-migrants (smolt), juvenile rearing, and returning adults. It is likely that most adverse effects would be avoided here by confining construction to offshore areas. Little information exists on the possible use of these waters by marine fish. Therefore some specific research might be considered to identify any fish species which might occur seasonally. Finally, the beluga whale is perhaps the most important marine mammal within this area and could easily be disturbed during construction activities. An assessment of the potential for disturbance could be made by reviewing the noise generated by dredging and vessel activities, the acoustical sensitivity of the beluga, and the proximity of activity to local concentration/feeding areas (primarily the mouths of several rivers entering the upper inlet). We would be pleased to assist you in assessing possible impacts to the Cook Inlet beluga population.

There are no Threatened or Endangered species for which our agency is responsible that normally occur within the waters of the project area. The Threatened Steller (northern) sea lion has been observed here, but this occurrence would be uncommon.

Please contact Brad Smith at 271-5006 concerning any questions you might have, or to discuss future project planning.

Sincerely,

Jeanne L. Hanson

for Ronald J. Morris
Western Alaska Office Supervisor
Protected Resources
Management Division

U.S. Army Corps of Engineers
Regulatory Branch
ATTN: LIZETTE BOYER
P.O. Box 898
Anchorage, AK 99506-0898

MEMORANDUM
STATE OF ALASKA

Office of Management and Budget
DIVISION OF GOVERNMENTAL COORDINATION
3601 "C" Street, Suite 370
Anchorage, Alaska 99503
Telephone: (907) 561-6131 Fax: (907) 561-6134

RECEIVED
MAR 0 8 1995
REGULATORY FUNCTIONS BRANCH
Alaska District, Corps of Engineers

TO: ACMP Reviewers

DATE: March 5, 1995

FROM: Arlene Murphy AM
Project Review Coordinator

FILE NO: AK9503-02AA

SUBJECT: Cook Inlet Deep-Draft Navigation Feasibility Study, ER-95-5
Anchorage Port facilities dredging
Maintenance dredging

Attached is a scoping document from the U.S. Army Corps of Engineers, Civil Works Branch for dredging a channel through a shoal in Cook Inlet to allow greater access for deep-draft shipping into Anchorage Port facilities.

This document has been prepared to satisfy the requirements of the National Environmental Policy Act (NEPA). Therefore, the State should review this document in accordance with NEPA and provide comments and suggestions on the full range of issues and plans presented. The NEPA regulations (see 1501.1 of 40 CFR) emphasize that cooperative consultation among agencies should occur before preparation of the environmental document, rather than agencies submitting adversary comments on the final document. This consultation should identify environmental effects and values in adequate detail (so they can be compared, per section 1501.2, to economic and technical analysis). The purpose of the enclosed document is to identify the significant issues related to a proposed action.

Should the federal agency determine that the activity would directly affect the coastal zone per 15 CFR 930.33, a formal determination of this project's consistency with the Alaska Coastal Management Program (ACMP) will be prepared later in the planning process. However, the State should take this opportunity to preliminarily address potential ACMP consistency issues of this project. In your response, comments relating to the project's consistency with the ACMP should be identified separately from the NEPA comments.

Please comment directly to the federal agency with a copy to DGC by **March 21st.**

Attachment

cc: Lizette Boyer, COE
Tim Smith, DNR, SHPO
Don McKay, DFG
Larry Bullis, DNR
Elaine Pistoresi, DEC
Thede Tobish, MOA

U.S. Department
of Transportation

United States
Coast Guard

Commanding Officer
U.S. Coast Guard
Marine Safety Office

510 L Street, Suite 100
Anchorage, AK 99501
Phone: (907) 271-6700

16000
8 Mar 95

From: Commanding Officer, Marine Safety Office Anchorage
To: U. S. Army Corps of Engineers, Alaska District

Subj: COOK INLET DEEP DRAFT FEASIBILITY STUDY

1. I encourage the expeditious approval of this proposal. The Coast Guard continues to have concerns about the shoaling problem in the vicinity of Knik Arm shoal.

2. I anticipate that the proposed dredging and maintenance schedule will have minimal effect on vessel traffic in Cook Inlet.

E. P. THOMPSON

Copy: CCGD17 (oan), (m)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
222 West 7th Avenue, Box 43
Anchorage, Alaska 99513-7577

March 20, 1995

Colonel Peter A. Topp
District Engineer
U.S. Army Corps of Engineers
Alaska District
P.O. Box 898
Anchorage, Alaska 99506-0898

Re: ER 95-5

Attn: CENPA-EN-CW-ER (Boyer)

Dear Colonel Topp:

Reference is made to your public notice dated February 21, 1995, with regards to the Cook Inlet Deep-Draft Navigation Feasibility Study.

The National Marine Fisheries Service has reviewed the preliminary information you have provided, and has no specific comments or recommendations at this time. We look forward to reviewing your forthcoming environmental assessment.

We remain willing to assist you with those living marine resource issues which may be identified during your review. Thank you for the opportunity to comment.

Sincerely,

Ronald J. Morris
Western Alaska Office Supervisor
Protected Resources
Management Division

NMFS Contact Person: Jeanne L. Hanson

cc: ADEC, ADFG, DGC, EPA, USFWS: Anchorage

TONY KNOWLES, GOVERNOR

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF LAND
SOUTHCENTRAL REGION

3601 C STREET, SUITE 1080
ANCHORAGE, ALASKA 99503-5937

March 21, 1995

Lizette Boyer
Environmental Resources Section
ATTN: CENPA-EN-CW-ER
U.S. Army Corps of Engineers
P.O. Box 898
Anchorage, Alaska 99506-0898

Re: I.D. Number ER 95-5 - Cook Inlet Deep-Draft Navigation Feasibility Study

The Alaska District of the U.S. Corps of Engineers is studying the feasibility of dredging a channel through a shoal in Cook Inlet to allow greater access for deep-draft shipping into Anchorage Port facilities. The channel would be aligned along the southern flank of Knik Arm.

Initial dredging would be to 39 feet at low tide and is estimated to involve 290,000 cubic yards. The proposed channel would be 800 feet wide and 4,000 feet long, and would allow for safe navigation in the worst of icy winter conditions. Maintenance dredging quantities are estimated not to exceed 80,000 cubic yards with a dredging frequency every second year. The proposed disposal site is a deeper water area near Fire Island. The majority of the dredged material would be sand and gravel. Samples taken from the disposal site indicated that the sea bottom is also composed of sand and gravel.

Initial channel dredging is expected to take 2 months during the ice-free period. Each episode of maintenance dredging is expected to take 3 weeks.

The Cook Inlet is state-owned tide and submerged land under the management jurisdiction of the Department of Natural Resources, Division of Land. However, no authorization from for the Division of Land for the dredging project should be necessary considering the disposal site for the dredged material would also be on state-owned tide and submerged land.

Based upon the provided information, the Division of Land has no objections to the proposed project, nor does it have concerns or comments at the present time related to the ACMP or the NEPA.

Larry Bullis

Larry Bullis
ACMP Liaison

cc: Arlene Murphy, DGC

TONY KNOWLES, GOVERNOR

OFFICE OF THE GOVERNOR

OFFICE OF MANAGEMENT AND BUDGET
DIVISION OF GOVERNMENTAL COORDINATION

☑ SOUTHCENTRAL REGIONAL OFFICE
3601 "C" STREET, SUITE 370
ANCHORAGE, ALASKA 99503-5930
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☐ CENTRAL OFFICE
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JUNEAU, ALASKA 99811-0300
PH: (907) 465-3562/FAX: (907) 465-3075

☐ PIPELINE COORDINATOR'S OFFICE
411 WEST 4TH AVENUE, SUITE 2C
ANCHORAGE, ALASKA 99501-2343
PH: (907) 278-8594/FAX: (907) 272-0690

March 28, 1995

Lizette Boyer
Environmental Resources Section
ATTN: CEPA-EN-CW-ER
U.S. Army Corps of Engineers
P.O. Box 898
Anchorage, AK 99506-0898

Dear Ms. Boyer:

SUBJECT: **NEPA REVIEW COMMENTS**
ER 95-5 - Cook Inlet Deep-Draft
STATE I.D. NO. AK9503-02AA

The Division of Governmental Coordination distributed the information you provided for your proposed project and requested the Alaska Coastal Management Program (ACMP) reviewers to identify ACMP consistency issues and submit NEPA comments.

Attached are comments received to date.

Thank you for the opportunity to participate at this early stage in the review process.

Sincerely,

Arlene Murphy

Arlene Murphy
Project Review Coordinator

cc: Lizette Boyer, COE
Tim Smith, DNR, SHPO
Don McKay, DFG
Larry Bullis, DNR
Elaine Pistoresi, DEC
Thede Tobish, MOA

MEMORANDUM

State of Alaska

DEPARTMENT OF FISH & GAME

TO: Faye E. Heitz
Project Review Coordinator
Division of Governmental Coordination
Office of Management and Budget

FROM: Donald O. McKay
Habitat Biologist
Region II
Habitat and Restoration Division
Department of Fish and Game

DATE: 13 March 1996

FAX NO.: 267-2464

TELEPHONE NO.: 267-2285

SUBJECT: Deep-Draft Navigation Feasibility Report
Cook Inlet, Alaska
SID AK9602-38AA
ER 96-9

The Alaska Department of Fish and Game (ADF&G) is unable to review the subject feasibility report. However, to avoid conflicts with salmon returning to Ship Creek, and commercial set gill net fishing at Fire Island, we recommend that dredging and spoil disposal occur between 15 August and 15 May.

Thanks for the opportunity to comment.

cc: B. Stratton, ADF&G
K. Tarbox, ADF&G
T. Tobish, MOA
T. Rumfelt, DEC
A. Iliff, DNR
L. Boyer, COE

(see related conversation record dated March 22, 1996)

CONVERSATION RECORD

CONVERSATION RECORD	TIME 11:50	DATE March 22. 1996

TYPE ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☐ INCOMING ☒ OUTGOING

Location of Visit /Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
Mr. Don McKay	AK Dept. of Fish and Game Anchorage Habitat Office	276-2279

ROUTING	
NAME/SYMBOL	INT
McConnell	
Smith	

SUBJECT

Cook Inlet Deep-Draft Navigation Project Fish and Game dredging window

SUMMARY

Fish and Game stated in a memo to the Divison of Governmental Coordination (DGC) dated 13 March that a dredging window was needed to protect salmon migration. They wanted dredging to only take place between August 15 through May 15. A meeting was arranged on March 20 to discuss this window. The Corps believed that this window would not allow safe and cost effective dredging of the Cook Inlet shoal. The Corps needs to have at least a 90-day period during the ice-free season to dredge in Cook Inlet. The Cook Inlet Deep-Draft project was discussed in detail. Some of the points made were that no increased turbidity would result from dredging and disposal of the course-grained materials. No materials would re-deposit onto Fire Island. The channel to be dredged is 6 miles from Ship Creek and would not significantly affect migrating salmon or commericial or sport fishing.

Mr. McKay re-thought his position on the dredging window and decided that the project is sufficiently distant from Ship Creek and Fire Island that no dredging window would be necessary. The chance of disruption would be minimal. He did advise that dredging earlier in the ice-free season would be optimal. He said he would write or call DGC (Faye Heitz) to cancel his earlier memo recommending a window.

ACTION REQUIRED
None

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Ms. Lizette Boyer	Lizette Boyer	March 25, 1996

ACTION TAKEN

SIGNATURE	TITLE	DATE

CONVERSATION RECORD

OPTIONAL FORM 271 (12-76)
DEPARTMENT OF DEFENSE

CONVERSATION RECORD

CONVERSATION RECORD	TIME 1:45	DATE March 21, 1996

TYPE ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☒ INCOMING ☐ OUTGOING

Location of Visit /Conference:

ROUTING	
NAME/SYMBOL	INT
McConnell	
Smith	

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
Tim Smith	State Historic Preservation Office Office of History and Archeology	269-8721

SUBJECT

Cook Inlet Deep-Draft Navigation Feasibility Report

SUMMARY

Tim Smith agreed that there would be no effect to cultural resources as a result of the Cook Inlet Deep-Draft Navigation project since this is solely a dredging and disposal action in the inlet.

ACTION REQUIRED

None

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Ms. Lizette Boyer	Lizette Boyer	March 21, 1996

ACTION TAKEN

SIGNATURE	TITLE	DATE
Guy R McConnell	Ch. Env Res. Section	22 mar 96

CONVERSATION RECORD

OPTIONAL FORM 271 (12-76)
DEPARTMENT OF DEFENSE

TONY KNOWLES, GOVERNOR

OFFICE OF THE GOVERNOR

OFFICE OF MANAGEMENT AND BUDGET
DIVISION OF GOVERNMENTAL COORDINATION

☑ SOUTHCENTRAL REGIONAL OFFICE
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☐ PIPELINE COORDINATOR'S OFFICE
411 WEST 4TH AVENUE, SUITE 2C
ANCHORAGE, ALASKA 99501-2343
PH: (907) 271-4317/FAX: (907) 272-0690

March 29, 1996

Certified Mail
Return Receipt Requested
#P 479 042 453

U.S. Army Corps of Engineers
ATTN: Lizette Boyer
PO Box 898
Anchorage, AK 99515-0898

Dear Ms. Boyer:

SUBJECT: PROPOSED CONSISTENCY FINDING
Deep-Draft Navigation Feasibility Report
Cook Inlet, Alaska
STATE I.D. NUMBER AK 9602-38AA

The Division of Governmental Coordination (DGC) is currently coordinating the State's review of your proposed federal activity for consistency with the Alaska Coastal Management Program (ACMP). This consistency determination applies to the federal consistency determination required for the project per 15 CFR 930 Subpart C. The State has developed this proposed consistency finding based on reviewers' comments.

The project is a federal civil works dredging project. The channel will be 1,000' wide, 6,562' long and 42' deep. The initial dredging quantity is 1,109,918 cubic yards. maintenance dredging every 5 years to maintain project depth is estimated at 520,037 cubic yards. The channel will benefit shipping into the Port of Anchorage. Dredged material disposal is in a deep water area near Fire Island. the dredged material is sand and gravel. The purpose of the project is for the shipping channel to increase access in all tidal stages, resulting in shipping cost benefits and increased safety. The project location is Cook Inlet, near Anchorage, Alaska.

Based on the review of your project by the Alaska Departments of Natural Resources, Environmental Conservation, and Fish and Game, and the Anchorage Coastal District, the State agrees the activity is consistent to the maximum extent practicable as proposed.

The following State permit is needed for the project:

Alaska Department of Environmental Conservation (DEC) - Certificate of Reasonable Assurance

Please contact me within five days of your receipt of this proposed finding to indicate whether or not you concur with this finding. If you are not prepared to concur within the five-day period, you may either:

(a) request an extension of the review schedule, if you need more time to consider this finding, or

(b) request that the state reconsider this finding, by submitting a written statement requesting "elevation" of the finding, describing your concerns, and proposing as alternative consistency finding, This alternative finding must demonstrate how your project is consistent with the referenced standards of the ACMP and district policies without the stipulations included in this proposed finding.

If I do not receive your request for extension or an elevation statement from you, or any other reviewing party with elevation rights as per 6 AAC 50.070(j), within five days of receipt of this letter, this proposed finding will be issued as a final conclusive consistency determination.

Other Concerns/Advisories
Please be advised that although the State has found the project consistent with the ACMP, based on your project description and any modifications contained herein, you are still required to meet all applicable State and federal laws and regulations. Your consistency determination may include reference to specific laws and regulations, but this in no way precludes your responsibility to comply with other applicable laws and regulations.

If changes to the approved project are proposed prior to or during its siting, construction, or operation, you are required to contact this office immediately to determine if further review and approval of the revised project is necessary. If the actual use differs from the approved use contained in the project description, the State may amend the State approvals listed in this consistency determination.

Should cultural or paleontological resources be discovered as a result of this activity, we request that work which would disturb such resources be stopped, and that the State Historic Preservation Office (762-2626) be contacted immediately so that consultation per section 106 of the National Historic Preservation Act may proceed

If you have questions regarding this process, please contact me at 269-7474.

Sincerely,

Faye E. Heitz

Faye E. Heitz
Project Review Coordinator

cc: Don McKay, DFG
Tim Rumfelt, DEC
Thede Tobish, MOA
Tim Smith, DNR, SHPO

APPENDIX A
ENGINEERING

Part 3 - Baseline Cost Estimate

RECOMMENDED PLAN, G.I.STUDY -13 MLLW — **** TOTAL PROJECT COST SUMMARY **** — PAGE 1 OF 2

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE FEASIBILITY REPORT, DATED: APRIL 1996
PROJECT: KNIK ARM SHOAL - CHANNEL EXCAVATION — DISTRICT: ALASKA
LOCATION: COOK INLET, ALASKA — P.O.C.: FRANK J. ANTOLIN, CHIEF, COST ENGINEERI

		CURRENT MCACES ESTIMATE PREPARED: 10 JAN 96 EFFECTIVE PRICING LEVEL: 10 JAN 96				AUTHORIZ./BUDGET YEAR: 1997 EFFECT. PRICING LEVEL: 1 OCT 95			FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	COST ($K)	CNTG ($K)	TOTAL ($K)			COST ($K)	CNTG ($K)	FULL ($K)
C-090101	MOB/DEMOB & PREP WORK	404	81	20%	485	404	81	485	JUL 97	6.1%	429	86	515
C-090102	DREDGING	3,329	666	20%	3,995	3,329	666	3,995	JUL 97	6.1%	3,531	706	4,237
TOTAL CONSTRUCTION COSTS =====>		3,733	747	20%	4,480	3,733	747	4,480			3,960	792	4,752
P-01	LANDS AND DAMAGES	0	0	0%	0	0	0	0	JUL 97	6.1%	0	0	0
P-30	PLANNING, ENGINEERING AND DESIGN	167	33	20%	200	167	33	200	JUL 97	6.1%	177	35	212
P-31	CONSTRUCTION MANAGEMENT	297	59	20%	356	297	59	356	JUL 97	6.1%	315	63	378
TOTAL PROJECT COSTS ==========>		4,197	839	20%	5,036	4,197	839	5,036			4,452	890	5,342
TOTAL FEDERAL COSTS ==============>													
TOTAL NON-FEDERAL COSTS ==========>													

THIS TPCS REFLECTS A PROJECT COST CHANGE OF $ ______________

THE MAXIMUM PROJECT COST IS =======> $ ______________

DISTRICT APPROVED:

______ CHIEF, COST ENGINEERING
______ CHIEF, REAL ESTATE
______ CHIEF, PLANNING
______ CHIEF, ENGINEERING
______ CHIEF, CON-OPS
______ CHIEF, PROGRAMS MANAGEMENT
______ PROJECT MANAGER
______ DDE (PM)

DIVISION APPROVED:

______ CHIEF, COST ENGINEERING
______ DIRECTOR, REAL ESTATE
______ CHIEF, PROGRAMS MANAGEMENT
______ DIRECTOR OF PPMD

APPROVED DATE: ______________

CONTRACT A **** TOTAL CONTRACT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE FEASIBILITY REPORT, DATED: APRIL 1996
PROJECT: KNIK ARM SHOAL - CHANNEL EXCAVATION
LOCATION: COOK INLET, ALASKA
DISTRICT: ALASKA
P.O.C.: FRANK J. ANTOLIN, CHIEF, COST ENGINEERI

ACCOUNT NUMBER	FEATURE DESCRIPTION	CURRENT MCACES ESTIMATE PREPARED: 10 JAN 96 EFFECTIVE PRICING LEVEL: 10 JAN 96 COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	AUTHORIZ./BUDGET YEAR: 1997 EFFECT. PRICING LEVEL: 1 OCT 95 OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FULLY FUNDED ESTIMATE FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
C-090101	MOB/DEMOB & PREP WORK	404	81	20%	485		404	81	485	JUL 97	6.1%	429	86	515
C-090102	DREDGING	3,329	666	20%	3,995		3,329	666	3,995	JUL 97	6.1%	3,531	706	4,237
	TOTAL CONSTRUCTION COSTS ==>	3,733	747	20%	4,480		3,733	747	4,480			3,960	792	4,752
P-01	LANDS AND DAMAGES	0	0	0%	0		0	0	0	JUL 97	6.1%	0	0	0
P-30	PLANNING, ENGINEERING AND DESIGN	167	33	20%	200		167	33	200	JUL 97	6.1%	177	35	212
P-31	CONSTRUCTION MANAGEMENT	297	59	20%	356		297	59	356	JUL 97	6.1%	315	63	378
	TOTAL COSTS ==>	4,197	839	20%	5,036		4,197	839	5,036			4,452	890	5,342

Knik Arm Shoal - Ch. Exc. -13.0m
Anchorage, Alaska

K:\MCACES\DREDGING\RFC002\FEASI
BIL\FSD130

Designed By: U. S. Army Corps Of Engineers
Estimated By: CENPA-EN-CE

Prepared By: SeeKwan Tan/Zimmermann

Preparation Date: 01/10/96
Effective Date of Pricing: 01/10/96
Est Construction Time: 135 Days

Sales Tax: 0.00%

SUMMARY REPORTS — SUMMARY PAGE

DETAILED ESTIMATE — DETAIL PAGE

No Backup Reports...

* * * END TABLE OF CONTENTS * * *

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Wed 10 Jan 1996
Eff. Date 01/10/96

PROJECT FSD130: U.S. Army Corps of Engineers
Knik Arm Shoal - Ch. Exc. -13.0m - Anchorage, Alaska
** Feasibility Study Estimate **
** PROJECT OWNER SUMMARY - Element (Rounded to 10's) **

27 05

TIME 10:41:03
SUMMARY PAGE 1

	QUANTITY UOM	CONTRACT	UNIT COST	TOTAL COST
09 Channels and Canals				
09_01 Channels				
09_01. 9 CHANNEL -13.0 MLLW				
09_01. 9.01 Mob, Demob, & Prep work		403,700		403,700
09_01. 9.02 Dredging	848600.00 M3	3,262,430	3.84	3,262,430
09_01. 9.03 Bid Item #3 Hydrographic Surveys	6.00 EA	66,070	11012.41	66,070
TOTAL CHANNEL -13.0 MLLW		3,732,210		3,732,210
TOTAL Channels		3,732,210		3,732,210
TOTAL Channels and Canals		3,732,210		3,732,210
TOTAL Knik Arm Shoal - Ch. Exc. -13.0m		3,732,210		3,732,210

Wed 10 Jan 1996
Eff. Date 01/10/96

PROJECT FSD130: U.S. Army Corps of Engineers
Knik Arm Shoal - Ch. Exc. -13.0m - Anchorage, Alaska
** Feasibility Study Estimate **
** PROJECT INDIRECT SUMMARY - Element (Rounded to 10's) **

27 06

TIME 10:41:03
SUMMARY PAGE 2

	QUANTITY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND&INS	TOTAL COST	UNIT COST
09 Channels and Canals								
09_01 Channels								
09_01. 9 CHANNEL -13.0 MLLW								
09_01. 9.01 Mob, Demob, & Prep work		322,600	20,960	24,050	33,270	2,830	403,700	
09_01. 9.02 Dredging	848600.00 M3	2,607,000	169,380	194,350	268,850	22,840	3,262,430	3.84
09_01. 9.03 Bid Item #3 Hydrographic Surveys	6.00 EA	52,800	3,430	3,940	5,450	460	66,070	11012.41
TOTAL CHANNEL -13.0 MLLW		2,982,400	193,770	222,330	307,560	26,130	3,732,210	
TOTAL Channels		2,982,400	193,770	222,330	307,560	26,130	3,732,210	
TOTAL Channels and Canals		2,982,400	193,770	222,330	307,560	26,130	3,732,210	
TOTAL Knik Arm Shoal - Ch. Exc. -13.0m		2,982,400	193,770	222,330	307,560	26,130	3,732,210	

LABOR ID: ANCH95 EQUIP ID: ALASKA Currency in DOLLARS CREW ID: ANCH95 UPB ID: ANCH95

NAVIGATION IMPROVEMENT AT KNIK ARM SHOAL
COOK INLET, ALASKA

APPENDIX B
ECONOMICS

CONTENTS

CONTENTS--Continued

FIGURES

TABLES

CONTENTS--Continued

TABLES--Continued

NAVIGATION IMPROVEMENT AT KNIK ARM SHOAL COOK INLET, ALASKA

APPENDIX B ECONOMICS

1. OVERVIEW

The economic analysis for the upper Cook Inlet navigation study focuses on changes in transportation cost. Most of the benefits are derived from two firms that have dedicated cargo liner service to the Port of Anchorage. The transportation savings are from efficiencies gained by the existing transportation system, not from a reallocation of commodities to a more efficient fleet. All figures are for the years stated; the price level is that of January 1996.

2. LOCATION AND DESCRIPTION

The Port of Anchorage is located on the southeast side of Knik Arm at the northern end of Cook Inlet, Alaska. The controlling depth at the Port of Anchorage is -10.7 m MLLW. The port is 325 kilometers (km) from the nearest entrance to Cook Inlet and 2,697 km from Seattle, Washington. Anchorage is the State's largest city and is centrally located with respect to Interior Alaska and the Kenai Peninsula. Fairbanks, the second largest city, is 590 km north of Anchorage and is linked to the Port of Anchorage by both the Alaska Railroad and the State's highway system. The Port of Anchorage was developed as the primary port of entry for Southcentral and Interior Alaska for general cargo; the port serves 80 percent of Alaska's population. The development of containerization and trailer service capitalized on the port's central location, proximity to population centers, and access to rail and highway facilities. Semiweekly container and trailer services are operated by Sea-Land Freight Service, Inc. Totem Ocean Trailer Express, Inc. (TOTE) operates trailer service twice a week in the winter and three times a week in the summer. Seasonal bulk barge services are operated by Delta Western, Alaska Marine, and other barge lines.

Two shoals near the Port of Anchorage have caused delays to shipping: Fire Island Shoal and Knik Arm Shoal. Fire Island Shoal historically has been navigated on the south side. The south-side channel has a controlling depth of -9.5 meters (m) mean lower low water (MLLW) and is about 3 km wide. Today Fire Island Shoal is navigated on the north side, where a controlling depth of -14.6 m MLLW is available over a channel width of 3.6 km. The focus of this study is Knik Arm Shoal. It is located about 3.2 km west of Point Woronzof and 12.9 km southwest of Anchorage. The shoal's crest is -3.4 m MLLW. The natural channel, marked by two buoys during the ice-free season of May through October, has a controlling depth of -8.5 m MLLW south of the shoal's crest. (See figure 2-2, main report.)

3. EXISTING CONDITIONS

3.1 General

Operating procedures, labor contracts, and commodity data for 1995 were used to establish the existing condition. Operating procedures and labor contract information were taken from written correspondence and telephone interviews with the shippers and the stevedore union.

3.2 Vessel Operations

Sea-Land and TOTE have dedicated cargo liner services between the Port of Tacoma, Washington, and the Port of Anchorage. Sea-Land also provides feeder service to the Alaska island communities of Kodiak and Unalaska/Dutch Harbor on the return trip to Tacoma. Vessels carrying containerized cargo are scheduled to arrive at the Port of Anchorage before 7 a.m. This schedule is coordinated with the port, the stevedores, trucking firms, and the railroad. If the shippers arrive late, they are penalized by the stevedore rates, and they must reschedule with the truckers, the railroad, and their customers. Thus, late arrivals increase administrative costs and cause contractual problems. Departing vessels carry primarily seafood and empty containers.

3.2.1 Sea-Land Operations.

Sea-Land has three vessels that call at Anchorage: the *Alaska*, *Kodiak*, and *Tacoma*. The three vessels operate on a rotating basis. (Sea-Land has other vessels in its Alaska service, but they serve only Unalaska/Dutch Harbor.) The vessels start at the Port of Tacoma, leaving every Wednesday and Friday, and go to the Port of Anchorage. After offloading and reloading at Anchorage, the vessels head for the Port of Kodiak on Kodiak Island. From Kodiak, the vessels either travel to Unalaska, on the Aleutian chain, or go back to Tacoma. The vessels that travel to Unalaska then return to Tacoma.

The voyage starts in Tacoma with the loading of the vessel. The dock that Sea-Land uses in Tacoma has a controlling depth of -13.7 m MLLW. Loading starts at 6 p.m. PST. Loading and unloading takes less than 8 hours, using three cranes. Once the vessel is loaded, it leaves around 2 a.m. PST the following day. The vessel can be delayed in the Port of Tacoma because of bad weather in the Gulf of Alaska. A coastal pilot navigates the vessel from the Port of Tacoma to Port Angeles. At Port Angeles, the pilot is picked up by a tug and taken to shore. Sea-Land expects the vessel to take 76 hours from port to port, a distance of 2,697 km.

From Port Angeles the captain navigates the vessel to Kenai, Alaska, near the mouth of Cook Inlet, at an average speed of 35.7 kilometers per hour (km/h). The vessel slows down at Kenai to pick up a coastal pilot, flown by helicopter from the Kenai Airport. If the helicopter cannot fly because of weather conditions, a tug transports the pilot to the vessel. From Kenai it will take the vessel 3 to 4 hours to reach Knik Arm Shoal and an additional hour to reach the dock at the Port of Anchorage.

The primary tool used to navigate Cook Inlet is radar. As the vessel approaches the Knik Arm shoal, both radar and range lines are used to navigate. Global Positioning System (GPS) instrumentation is not used because it does not provide feedback as quickly as radar and range lines and is more labor-intensive. However, radar and range lines do not provide the confidence level needed to cross this shoal during adverse weather conditions. Conditions such as fog, snow, and heavy rains limit visibility, and this limited visibility prevents the usage of range lines. Without range lines the pilot becomes extremely conservative, increasing the amount of underkeel clearance. This slows the vessel down and can make it late arriving at the Port of Anchorage.

In addition to weather delays, there can be delays caused by lack of sufficient water depth to cross Knik Arm Shoal. The pilot begins timing the vessel's arrival at the shoal from the time he first boards the vessel, in Kenai. Options used to optimize arrival time include slowing the vessel's speed throughout Cook Inlet, circling in the lower inlet, or anchoring the vessel.

Sea-Land vessels can dock on either the port or the starboard side. Because the vessel can dock on either side, the pilot can dock either on the flood or the ebb tide. The pilot needs a flood or ebb tide to navigate the vessels into the dock. Without the tide, the pilot has little control over the ship.

Delays from weather or water levels have an adverse impact on the loading and unloading operations at the Port of Anchorage. The unloading process is most cost-effective (costs least in stevedore wages) if it begins at 7 a.m. The best time for Sea-Land to arrive is around 5 a.m. to be ready for a 7 a.m. start. Offloading and reloading the empty containers takes 12 to 15 hours.

After the vessel is unloaded and loaded, it takes about an hour to travel from the dock to the shoal. After crossing the shoal, the coastal pilot navigates the vessel to Kodiak Island. From the Port of Anchorage to the Port of Kodiak is 448 km, or 13 hours. The Port of Kodiak has a controlling depth of -12.2 m at MLLW. It usually takes about 4 or 5 hours to load and unload the vessel at Kodiak. Depending on the voyage, the vessel then either returns to Tacoma or heads to Unalaska.

Traveling from Kodiak to Unalaska, a distance of 1,050 km, takes about 30 hours. The dock Sea-Land uses at Unalaska has a controlling depth of -12.2 m MLLW. Loading and unloading at Unalaska takes approximately 12 hours. After leaving Unalaska the vessel returns to Port Angeles, Washington, a distance of 2,917 km or 85 hours. For vessels traveling from Kodiak to Port Angeles, the distance is 2,539 km or 72 hours. From Port Angeles to the Port of Tacoma, it is 209 km or 6 hours. Vessels usually arrive in Tacoma before 6 p.m. PST, and the process of unloading and loading starts again.

3.2.2 TOTE Operations.

TOTE has three vessels in its Alaska operations: the *Greatland, Northern Lights*, and *Westward Venture*. The vessels leave from the Port of Tacoma, travel to the Port of Anchorage, and return to Tacoma. A vessel departs Tacoma every Thursday and Saturday; in the summer only, a third vessel departs on Tuesday.

The vessels are first loaded in Tacoma. The dock that TOTE uses there has a controlling depth of -13.7 m MLLW. The vessels are usually loaded in less than 8 hours. On Wednesdays and Fridays, summer and winter, vessels start loading at 6 p.m. PST. These vessels leave for Anchorage around 1 or 2 a.m. on Thursdays and Saturdays. In summer, the third vessel begins loading on Tuesdays at 8 a.m. PST. and departs for Anchorage about 5 or 6 p.m. the same day. TOTE expects the vessels to take about 66 hours from port to port, a distance of 2,697 km.

The vessels leave Tacoma with a coastal pilot who can guide TOTE vessels in both Puget Sound and Cook Inlet. The captain of the TOTE vessel takes over at Port Angeles. Captains try to maintain a speed of 41.4 kilometers/hour (km/h). The coastal pilot assumes control again at Anchor Point, Alaska, and takes the ship to the Port of Anchorage. From Anchor Point, it will take the vessel 3 to 4 hours to reach the shoal and an additional hour to reach the dock at the Port of Anchorage.

As with Sea-Land, the primary tool used to navigate Cook Inlet is radar. As the vessel approaches the Knik Arm shoal, both radar and range lines are used. GPS instrumentation is not used because it does not provide feedback as quickly as radar and range lines and is more labor-intensive. However, radar and range lines are not precise enough for navigation across the shoal during the worst weather conditions. Limited visibility precludes the use of range lines, and pilots become more conservative, increasing the amount of underkeel clearance.

In addition to weather delays, there can be delays caused by lack of sufficient water depth to cross the shoal. Unlike the Sea-Land vessels, TOTE vessels need a flood tide to cross the shoal. The pilot begins at Anchor Point, near the mouth of Cook Inlet, to time the vessel's arrival at the shoal. As with Sea-Land, the pilot can choose to optimize the ship's arrival time by slowing the vessel speed throughout Cook Inlet, circling in the lower inlet, or anchoring the vessel.

TOTE vessels are further constrained by being able to dock only on the port side. This is caused by the design of the Anchorage docking facility. Since TOTE vessels can dock only on the port side, they require a flood tide for docking.

Delays from weather or water levels have an adverse impact on loading and unloading operations at the Port of Anchorage. The unloading process is most cost-effective if it begins at 7 a.m. The best time for TOTE to arrive is around 5 a.m. to be ready for a 7 a.m. start. Offloading and reloading the empty containers takes 12 to 13 hours.

After the vessel is unloaded and loaded, it takes about an hour to travel from the dock to the shoal. After crossing the shoal, the pilot then guides the vessel back to Anchor Point, where the captain takes over and heads for Port Angeles, Washington. From Port Angeles to the Port of Tacoma, it is 209 km or 6 hours. The vessels usually arrive in Tacoma before 6 p.m. PST, and the process of unloading and loading starts again.

3.3 Tide and Shoal Considerations

Sea-Land pilots prefer to navigate upper Cook Inlet on a flood tide because it allows their vessels to gain a few kilometers per hour in speed. TOTE pilots almost always navigate upper Cook Inlet on a flood tide because of the ships' design and the design of the dock facilities at the Port of Anchorage.

Navigating the Knik Arm Shoal is sometimes difficult because of high winds, heavy ice, and strong currents. Combinations of these conditions can move the vessels significantly off an intended course. The U.S. Coast Guard removes the buoys marking the crest of Knik Arm Shoal during the winter months, November to May, because of heavy ice conditions. Fog, snow, and heavy rains can limit visibility, which precludes the use of visual ranges on shore 9.3 km or more away. Without visual ranges, the pilots are extremely conservative with regard to underkeel clearance.

Sea-Land can cross Knik Arm Shoal safely during an average high tide window of about 7 hours. The flood-tide window for TOTE vessels is about 4 hours. The high tide widow for TOTE is shorter because the TOTE vessels need a flood tide to dock at the Port of Anchorage. Ice floes or storms occasionally cause both Sea-Land and TOTE vessels to miss the high tide window, forcing a delay of a full tide cycle as they wait for the next high tide.

Once a vessel is offloaded at the Port of Anchorage, the marine manager must decide when to depart. This departure decision must balance the need to time the tidal access, the need to load the cargo, and the need to reload the empty containers. Two shoal-related conditions may complicate this decision. First, the outbound vessel may face an upcoming tide window that can be met only if outbound cargo or empty containers are left behind. Second, the outbound ship may be ready to sail but must sit idle at the dock waiting for the next high tide window.

4. WITHOUT-PROJECT CONDITION

The without-project condition is the most likely condition expected to exist over the life of the project in the absence of a Federal investment. Without the proposed channel excavation, container vessels will continue to experience shoal-induced delays and related problems. As commodity flows increase though the Port of Anchorage, the frequency of delays will increase proportionately.

Without the proposed channel excavation, Sea-Land pilots assume a shoal crossing area 732 meters wide with a controlling depth of -8.5 meters at MLLW. TOTE pilots assume a shoal crossing area 926 meters wide with a controlling depth of -8.5 meters. The reason for the difference in the width of the assumed crossing area is related to the draft of the vessels. Both Sea-Land and TOTE pilots use a minimum of 3 meters for underkeel clearance.

5. WITH-PROJECT CONDITION

The with-project condition is the condition expected to exist over the period of analysis if an excavated channel is provided through Knik Arm Shoal. For the feasibility study, five channel bottom elevations (-11, -11.5, -12, -12.5, and -13 m MLLW) were examined. Vessel operations were simulated at each depth to estimate the reduction in shoal-induced delays resulting from increased channel depth. A channel width of 245 meters was evaluated for this study. The channel will be dredged to 305 meters, but the U.S. Army Corps of Engineers will guarantee only 245 meters between dredging cycles.

6. METHODOLOGY

Economic evaluation of the proposed channel improvement to the Knik Arm Shoal was conducted according to Engineering Regulation (ER) 1105-2-100, chapter 6, section VII, "NED [National Economic Development] Benefit Evaluation Procedures: Transportation, Deep-Draft Navigation," dated December 1990, and the Institute for Water Resources' "National Economic Development Procedures Manual: Deep Draft Navigation," dated 1991.

The economic benefits from the proposed Knik Arm Shoal project are the reduction in origin-to-destination transportation cost and the opportunity cost of time. The specific transportation savings result from reductions in fuel consumption, stevedore cost, administration cost, and insurance cost.

Project benefits were estimated by calculating the transportation cost for both with- and without project conditions on a per-trip basis. Historical and existing commodity movements were examined to determine commodity throughput and trends in commodity flows. For the benefit calculations, the last several years of cargo data were used as a base for the next 50 years. No future projections were included in the benefit calculations. The number of vessels, size of the vessels, and number of trips stayed constant over the 50-year period of analysis. Yearly transportation savings were estimated by multiplying the per-trip saving estimate times the number of trips per year through the planning period. Reduced costs were claimed as project benefits and compared to the project cost to derive a benefit-to-cost ratio.

Benefits attributable to the transportation of petroleum products were not quantified for this feasibility report. While the petroleum tonnage is close to the volume of general containerized cargo, the transportation savings are comparatively small because of the small number of trips per year.

7. PAST COMMODITY MOVEMENT

Prior to 1964, freight was moved throughout Southcentral Alaska by train from deep-water ports at Seward and Whittier. Steamship lines brought general cargo to Seward, where it was transferred to railcars and moved to the population centers at Anchorage, Palmer, and Fairbanks. From Seward, this involved a rail movement of about 200 km to Anchorage and 590 km to Fairbanks. The 200-km section between Seward and Anchorage traverses some of the steepest grades and most difficult terrain found on the Alaska Railroad system. Freight that required specialized handling, such as heavy machinery, pipes, and vehicles, was carried to Whittier by rail barge or train-ship and moved by the Alaska Railroad to major population centers.

Following the Good Friday earthquake of 1964, the Port of Anchorage emerged as the only operable deep-draft shipping facility in the region. As a result, major changes took place in waterborne transportation to the Alaska railbelt area. The steamship service to Seward was replaced by a modern fleet equipped to deliver containerized general freight to the developing Port of Anchorage. Freight could then be distributed by rail or truck to local businesses or to cities in the railbelt area. Import of materials in the 1970's for construction of the Trans-Alaska Pipeline further accelerated development of the Port of Anchorage. General cargo tonnage through Anchorage increased from 1,925,000 short tons in 1985 to 2,690,000 short tons in 1994.

Table 4-1 in the main report shows the historical flow of cargo through the Port of Anchorage. From 1991 through 1994, containers and trailer-van traffic averaged 55.7 percent of total throughput, petroleum traffic averaged 40.3 percent, and bulk commodities averaged 3.8 percent.

Figure B-1 shows the yearly arrivals by vessel type from 1985 to 1994.

8. EXISTING FLEET

The majority of cargo passing through the Port of Anchorage has been carried by deep-draft containerships or liquid-bulk petroleum vessels. A few dry-bulk carriers also call periodically. Many shallow-draft barges and tugs also serve the upper Cook Inlet. Barge and tug traffic is not expected to be significantly affected by the proposed channel excavation.

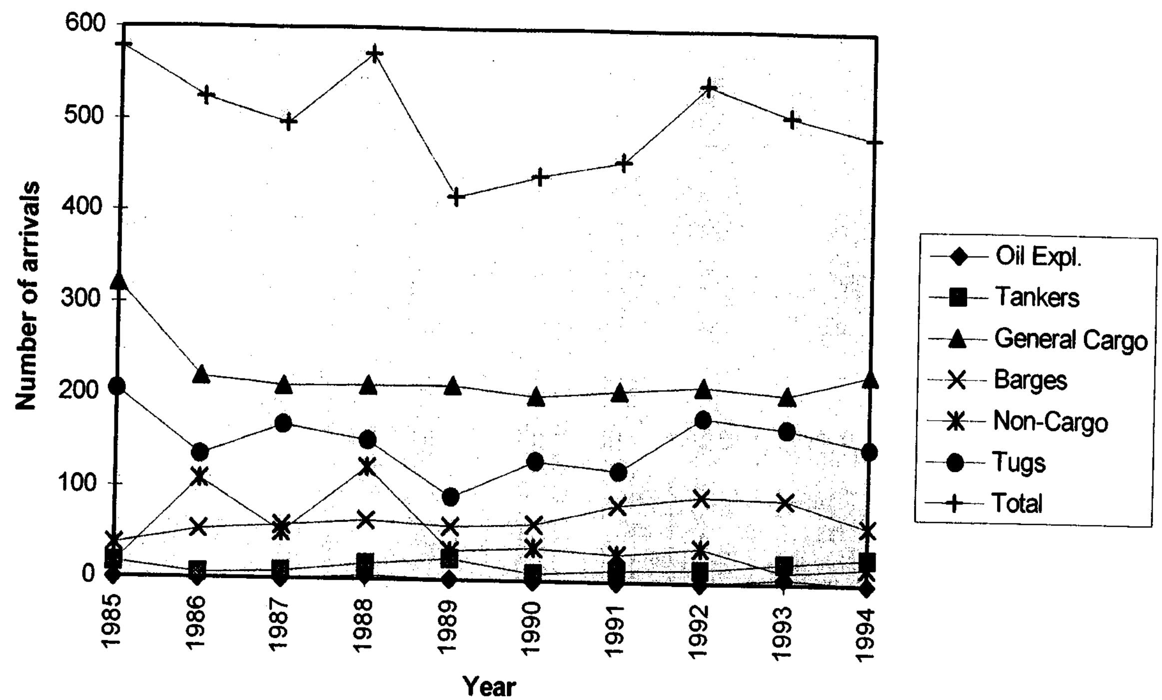

FIGURE B-1.--Port of Anchorage yearly vessel arrivals, 1985-94.

8.1 Containerized and RO/RO Vessels

Dedicated liner service to the Port of Anchorage is provided by the two shipping firms discussed earlier, Sea-Land and TOTE. Their vessels serving Anchorage are discussed in the following paragraphs.

Sea-Land has three containerized vessels: the *Anchorage*, the *Kodiak*, and the *Tacoma*. These vessels average 21,000 dwt mt (deadweight metric tons) and are equipped with 22,540 brake horsepower (BHP) propulsion systems. Sea-Land vessels can carry 721 40-foot (12.2-m) containers and have a maximum load of 10,500 metric tons (mt). The vessels usually have 21 crewmembers each. The *Anchorage*, *Kodiak*, and *Tacoma* were delivered to Sea-Land in 1987. They are expected to last until 2007.

The Sea-Land vessels have a top speed of 36.1 km/h and burn 3.33 tons of fuel per hour at top speed. Their engines are diesel-powered; they burn IFO 380 fuel for higher speeds and MDO for lower speeds. The ships use the two fuels for most efficient and cleanest fuel consumption. While the ships are at sea, IFO 380 is burned 80 percent of the time and MDO 20 percent of the time. The average cost of IFO 380 and MDO is $100 per ton, according to the Sea-Land ship superintendent. When the vessels are in the Port of Anchorage, auxiliary generators are used for ship power. (The vessels do not use any shore power.) The diesel generators burn 0.33 tons of fuel per hour.

TOTE has three roll-on, roll-off (RO/RO) vessels: the *Greatland*, *Northern Lights*, and *Westward Venture*. These vessels average 17,900 dwt mt and are equipped with 30,000-BHP propulsion systems. Each can carry 390 40-foot (12.2-m) trailers and about 126 vehicles, with a maximum load of 9,400 mt. The vessels usually have 30 crewmembers each. The *Greatland* was built in 1975 and retrofitted in the winter of 1994-1995. The *Northern Lights* was built in 1974 and retrofitted in 1993, when a 90-foot section was added. The *Westward Venture* was built in 1977 and retrofitted in the winter of 1993-1994. These vessels are expected to last until 2010.

The TOTE vessels have a top speed of 42.6 km/h; at this speed, the engines burn 7.46 tons of fuel per hour. The vessels are equipped with double steam turbines that burn bunker C fuel. TOTE managers report that this fuel costs $116 per ton. When the vessels are in the Port of Anchorage, the main engines are kept running to produce heat and power for the ship. (The vessels use no shore power.) The main engines at idle burn 0.83 tons per hour.

The vessels described above vary considerably in their speed and fuel consumption rates. TOTE vessels have older steam-powered systems which are less efficient than the modern diesel-powered engines that the Sea-Land vessels use. Steam-powered engines last significantly longer than diesel engines, however, which is why TOTE is likely to keep its steam power for the next 15 to 20 years. The characteristics of Sea-Land and TOTE vessels are listed in table B-1.

TABLE B-1.--*Characteristics of the Anchorage containership and RO/RO fleet*

Company	Weight (dwt, mt)	Type	Loaded draft (m)	Length (m)	Beam (m)
Sea-Land					
(3 vessels)[a]	20,700	container	10.5	216.4	23.8
TOTE					
(3 vessels)[b]	17,900	RO/RO	8.8	240.8	32

[a] *Anchorage, Kodiak,* and *Tacoma:* characteristics are the same.
[b] *Greatland, Westward Venture,* and *Northern Lights:* characteristics are the same.

8.2 Petroleum Vessels

Five petroleum tankers called at the Port of Anchorage in 1991. They are listed in table B-2 by name, weight, loaded draft, length, and beam.

TABLE B-2.--*Characteristics of petroleum vessels calling at Anchorage (1991)*

Name	Weight (dwt)	Loaded draft (m)	Length (m)	Beam (m)
Colorado	39,000	11.3	198.4	29.3
Sealift Antarctic	27,200	10.7	179	25.6
Star Montana	27,000	10.4	184.4	23.8
Flamenco	45,000	11.3	182.9	32.3
Alkuwaitah	35,000	11	183.9	32.3

9. TRANSPORTATION COST WITH AND WITHOUT THE PROJECT

Origin-to-destination transportation costs were estimated for the shippers' present operating procedures. Transportation costs from the ultimate point of origin to the Port of Anchorage would be affected by the project and are addressed in this analysis. Transportation costs estimated from the Port of Tacoma to the Port of Anchorage included both vessel-related costs and shoreside costs.

Operating costs for the containerized vessel fleet were estimated with the aid of the Corps of Engineers' Economic Guidance Memorandum (EGM) 95-2, "Fiscal Year 1995, Deep Draft Vessel Cost Estimates." EGM 95-2 estimates of cost for fuel consumption, administration, insurance, and maintenance were adjusted to conform to data provided by the shippers.

Future benefits for increased cargo are not included. The project is justified on the basis of existing commodity flows. Vessels currently servicing the Port of Anchorage are expected to be in service for the next 15 to 20 years unless significant changes are made to the docks.

9.1 Fuel Savings

Fuel consumption was estimated using information from the Corps' Headquarters Office, formerly Policy and Planning Division, Economics and Social Analysis Branch. The rate of fuel consumption was adjusted for changes in speed using a consumption function from the *Merchant Marine Officers' Handbook* (Turpin and MacEwen 1989). Vessels in the Alaska trade are significantly different from the average container or roll-on/roll-off vessel published in the "Economics Guidance Memorandum 95-2: Fiscal Year 1995 Deep Draft Vessel Cost Estimates." The Alaska vessels have more horsepower and are faster; therefore, they consume higher quantities of fuel.

Shoal-induced delays at the Port of Anchorage occur in two forms: (1) extra time spent in approaching Anchorage slowly in order to meet high tide at the shoal, and (2) time spent at the dock ready for departure waiting for high tide at the shoal. The shoal-induced delays for Sea-Land and TOTE vessels were calculated by a numerical model, which is described in more detail in appendix C. The ship transit simulation model was designed in the reconnaissance phase of this study to simulate pilot decisions and realistic application of their decisions for the transits of individual ships from their port of origin to Anchorage, their time at the dock, and their departure across the shoals. Minor modifications were made in the feasibility phase. It is a time-and-motion numerical model that simulates the tides of Cook Inlet, the approach of individual vessels, the decisions of pilots navigating Cook Inlet to Anchorage, and the effect of those decisions on vessel arrival and departure times. The computer program relies on data from records of the Port of Anchorage and from shipper-provided information on ship departures from port of origin, cargo loads, and vessel characteristics. These simulated delays were used to derive an average delay time. This average delay time was then used to calculate the benefits related to fuel consumption, stevedore overtime savings, and stevedore castoff savings. The model results excluded the effects of weather and ocean conditions, though ship captains and pilots have stated that weather and ocean conditions affect the vessel arrival times. These natural conditions would not be changed by the proposed project. Hours that could be saved during a year by the shoal channel project, excavated to several alternative depths, are shown in table B-3.

TABLE B-3.--*Shoal-induced delays in 1991 for Sea-Land and TOTE ships in upper Cook Inlet (simulation model results)*

Sea-Land

Channel depth (m)	Time at reduced speed (h) per year	Time waiting (h) per year	Change in hours
-8.5*	292.3	117.9	0
-11	112.5	17.6	-280.1
-11.5	78.4	1.0	-330.5
-12	37.8	0.0	-372.4
-12.5	18.7	0.0	-391.5
-13	3.9	0.0	-406.3

TOTE

Channel depth (m)	Time at reduced speed (h) per year	Time waiting (h) per year	Change in hours
-8.5*	425.1	12.4	0
-11	204.7	0.0	-232.8
-11.5	190.0	0.0	-247.5
-12	182.6	0.0	-254.9
-12.5	179.8	0.0	-257.7
-13	178.4	0.0	-259.1

* Without-project condition.

Sea-Land and TOTE prefer to cross the shoal between 5 and 6 a.m. to save on stevedore costs by arriving just at the start of a normal shift. The vessels usually rush to lower Cook Inlet, then adjust their speed from the inlet entrance to the shoal to accommodate the restricted tidal window. If the vessel misses a tidal window, the schedule slips, costing the shipper money to try to catch up. On the other hand, the tidal window can cause the shipper to reach the Port of Anchorage too early. For example, if high tide is at 2 a.m., the Sea-Land vessel might be able to cross the shoal between 10 p.m. and 6 a.m., and the TOTE vessel might be able to cross between midnight and 4 a.m. The vessel might cross the shoal at 2 a.m., arriving at the dock at 3 a.m. To save stevedore costs, the captain would still wait to offload the vessel until 7 a.m. In addition to burning more fuel because of adjusting their speed for the shoal, the vessels have the added shoreside cost of waiting for the 7 a.m. start.

In the without-project condition, the shippers travel across the Gulf of Alaska at nearly full speed and then slow down to cross the Knik Arm Shoal because they prefer to use additional fuel rather than miss a shoal crossing. With the project, the shippers would have larger windows to cross the shoal, allowing them to cross at more cost-effective times. For example, with an improved channel, Sea-Land might be able to cross the shoal between 6 p.m. and 8 a.m., and TOTE between 11 p.m. and 5 a.m. With a large tidal window, the shippers would no longer need to rush. They would slow down and travel at a more even rate over the whole trip from Tacoma to Anchorage. Since the shippers would not shorten the time of their trips by having a greater depth at the shoal, the time they would gain by not waiting so long for tide would be added to the scheduled trip time. This extra time (now spent waiting for tide at the shoal) would allow the vessels to slow down and save fuel by burning it at a lower rate over a longer period of time.

The following paragraphs and tables are devoted to calculating the fuel cost savings for Sea-Land and TOTE vessels with channels over Knik Arm Shoal at various depths. Sea-Land is considered first. The savings for both companies are summarized at the end of this subsection.

9.1.1 Sea-Land

Table B-4 shows the time savings for Sea-Land vessels with channels through Knik Arm Shoal at various depths. The time at reduced speed in hours per year (column 2) was taken from the model simulation results for Sea-Land as displayed in table B-3.

TABLE B-4.--*Sea-Land vessels' time savings with channels at various depths*

Depth (m)	Time at reduced speed (h)/year	No. of trips	Avg. time at reduced speed/trip (h)	Change in avg. time at reduced speed (h)
-8.5*	292.3	102	2.9	0.0
-11	112.5	102	1.1	-1.8
-11.5	78.4	102	0.8	-2.1
-12	37.8	102	0.4	-2.5
-12.5	18.7	102	0.2	-2.7
-13	3.9	102	0.0	-2.9

* Without-project condition.

In the without-project condition, the Sea-Land vessels reduce speed for 2.9 hours before crossing the shoal. On the return trips, the Sea-Land vessels wait an average of 1.2 hours. With a project, time would be added to the return trip, allowing the vessel to travel more slowly back to the Port of Tacoma. The vessels thus would spend more time at sea but burn less fuel per hour. (In reality, as discussed in subsection 3.2.1, the Sea-Land vessels continue on to Kodiak and sometimes to Unalaska before returning to Tacoma. The simulation model, however, assumed Tacoma-Anchorage-Tacoma round trips. The principle is the same.)

In table B-5, the change in average hours at reduced speed is added to the planned trip length to yield a new trip length in hours. A fuel consumption rate and the open-sea inbound fuel consumption, per trip, is then calculated. The shippers stated that with a shoal channel, each ship would travel at a slower speed over the whole trip, enabling the ships to burn less fuel.

TABLE B-5.--*Sea-Land trip lengths in hours, Tacoma-lower Cook Inlet, and open-ocean fuel use with channels at various depths*

Depth (m)	Planned trip length (h)	Change in avg. hours at reduced speed	New trip length (h)	Distance traveled (km)	Avg. speed (km/h)	Fuel consumption rate (tons/h)	Open-sea fuel consumption per trip (t)
-8.5*	73.1	0.0	73.1	2,608	35.7	3.20	233.9
-11	74.9	1.8	76.7	2,663	34.7	2.96	227.0
-11.5	75.2	2.1	77.3	2,672	34.6	2.92	225.7
-12	75.6	2.5	78.1	2,684	34.4	2.87	224.1
-12.5	75.8	2.7	78.5	2,691	34.3	2.85	223.7
-13	76.0	2.9	78.9	2,697	34.2	2.80	220.9

* Without-project condition.

The vessels would still have to slow down to cross the shoal, but the time spent at reduced speed would be less. Table B-6 shows the amount of fuel Sea-Land vessels would use in Cook Inlet with a shoal channel at various depths.

TABLE B-6.--*Sea-Land fuel used in Cook Inlet (lower Cook Inlet-Anchorage) with channels at various depths*

Depth (m)	Avg. hours at reduced speed	Avg. speed (km/h)	Fuel consumption rate (tons/h) at reduced speed	Total fuel used in inlet/trip
-8.5*	2.9	30.6	2.0	5.8
-11	1.1	30.6	2.0	2.2
-11.5	0.8	30.6	2.0	1.6
-12	0.4	30.6	2.0	0.8
-12.5	0.2	30.6	2.0	0.4
-13	0 0	30.6	2.0	0.0

* Without-project condition.

Table B-7 shows total Sea-Land fuel usage for the trip from Tacoma to Anchorage with hypothetical channels at various depths.

TABLE B-7.--*Total fuel used by Sea-Land vessels, Tacoma-Anchorage, with channels at various depths*

Depth (m)	Fuel used in open sea (t)	Fuel used in Cook Inlet (t)	Total fuel used/trip (t)
-8.5*	233.9	5.8	239.7
-11	227.0	2.2	229.2
-11.5	225.7	1.6	227.3
-12	224.1	0.8	224.9
-12.5	223.7	0.4	224.1
-13	220.9	0.0	220.9

* Without-project condition.

On the return trip to Tacoma, the shipper has to wait to cross the shoal at Anchorage. Table B-8 shows the number of hours the vessels must wait to cross the shoal leaving the Port of Anchorage. (This number would be zero for depths of -12 m MLLW and greater.)

TABLE B-8.--*Time Sea-Land vessels must wait to leave Port of Anchorage, with channels at various depths*

Depth (m)	Hours waiting at port/year	No. of trips	Hours/ trip	Change in waiting time/ trip (h)
-8.5*	117.9	102	1.2	0.0
-11	17.6	102	0.2	-1.0
-11.5	1.3	102	0.0	-1.2
-12	0.0	102	0.0	-1.2
-12.5	0.0	102	0.0	-1.2
-13	0.0	102	0.0	-1.2

* Without-project condition.

Table B-9 shows the new return trip lengths, calculated by adding the time gained (by not waiting at the Port of Anchorage to cross the shoal) to the planned trip length. This table also shows fuel consumption rates for the return trip and the total fuel used in the open sea per trip. As mentioned earlier, the distance traveled back to Tacoma from Anchorage is not empirically correct because all Sea-Land vessels stop at the Port of Kodiak after visiting Anchorage, and one vessel per week continues to Unalaska. To include the Kodiak and Unalaska segments would increase the complexity of the analysis but add no significant impact or meaning, since the diversions to Kodiak and Unalaska occur after the ships leave Cook Inlet. The ship transit simulation model assumed that the vessels journey from Tacoma to Anchorage to Tacoma, without deviation.

TABLE B-9.--*Sea-Land trip lengths in hours, Anchorage-Tacoma, and open-ocean fuel use with channels at various depths*

Depth (m)	Planned trip length (h)	Change in avg. waiting time (h)	New trip length (h)s	Distance traveled (km)	Avg. speed (km/h)	Fuel consumption rate (tons/h)	Open-sea fuel use per trip (t)
-8.5*	74.8	0.0	74.8	2,697	36.1	3.31	247.6
-11	75.8	1.0	76.8	2,697	35.1	3.06	235.0
-11.5	75.8	1.2	76.8	2,697	35.1	3.06	232.4
-12	76.0	1.2	77.2	2,697	34.9	3.01	232.4
-12.5	76.0	1.2	77.2	2,697	34.9	3.01	232.4
-13	76.0	1.2	77.2	2,697	34.9	3.01	232.4

* Without-project condition.

Table B-10 shows the amount of fuel Sea-Land vessels would use on the return trip waiting to leave the Port of Anchorage because of the shoal. (This number is zero for channel depths of -11.5 m MLLW and greater.)

TABLE B-10.--*Fuel Sea-Land vessels would use waiting to leave the Port of Anchorage, with channels at various depths*

Depth (m)	Hours waiting per trip	Fuel used at port (tons/h)	Fuel used waiting/trip (t)
-8.5*	1.2	0.33	0.4
-11	0.2	0.33	0.1
-11.5	0.0	0.33	0.0
-12	0.0	0.33	0.0
-12.5	0.0	0.33	0.0
-13	0.0	0.33	0.0

* Without-project condition.

Table B-11 shows the fuel usage in tons for Sea-Land vessels on the return trip from Anchorage to Tacoma, with channels at the various depths.

TABLE B-11.--*Total fuel used by Sea-Land vessels, Anchorage-Tacoma, with channels at various depths*

Depth (m)	Fuel used in open sea (t)	Fuel used waiting to leave port (t)	Total fuel used/trip (t)
-8.5*	247.6	0.4	248.0
-11	235.0	0.1	235.1
-11.5	232.4	0.0	232.4
-12	232.4	0.0	232.4
-12.5	232.4	0.0	232.4
-13	232.4	0.0	232.4

* Without-project condition.

Table B-12 shows the total fuel use and total fuel cost savings per year for Sea-Land with channels at the various depths. The total tons of fuel used per year multiplied by the cost in dollars per ton multiplied by the number of trips yields the change in fuel cost (savings) per year.

TABLE B-12.--*Sea-Land fuel cost savings per year with channels at various depths*

	Fuel used/year (t)						
Depth (m)	Tacoma/ Anchorage	Anchorage/ Tacoma	Total	Reduction in fuel use (t)	$/ton	No. of trips	Reduction in fuel cost/yr ($)
-8.5*	240	248	488	0	100	102	0
-11	229	235	464	-24	100	102	-244,800
-11.5	227	232	459	-29	100	102	-295,800
-12	225	232	457	-31	100	102	-316,200
-12.5	224	232	456	-32	100	102	-326,400
-13	221	232	453	-35	100	102	-357,000

* Without-project condition.

A channel over Knik Arm Shoal at a navigation depth of -11.5 m MLLW, then, would mean annual fuel cost savings of $296,000 for Sea-Land. (This number is further refined in subsection 9.1.3.)

9.1.2 TOTE.

The savings for TOTE are calculated the same way as for Sea-Land. Table B-13 shows the time savings for TOTE vessels with channels through Knik Arm Shoal at various depths. The time at reduced speed in hours per year (column 2) was taken from the model simulation results for TOTE as displayed in table B-3.

TABLE B-13.--*TOTE vessels' time savings with channels at various depths*

Depth (m)	Time at reduced speed (h)/year	No. of trips	Avg. time at reduced speed/trip(h)	Change in avg. time at reduced speed (h)
-8.5*	425.1	123	3.5	0.0
-11	204.7	123	1.7	-1.8
-11.5	190.0	123	1.5	-2.0
-12	182.6	123	1.5	-2.0
-12.5	179.8	123	1.5	-2.0
-13	178.4	123	1.5	-2.01

* Without-project condition.

The increased channel depths result in a decrease in the average delays for inbound and outbound traffic. However, these decreases are not consistent for inbound TOTE vessels. TOTE vessels can dock only on the port side because of the design of the docking facility at the Port of Anchorage. Since the vessel can dock only on the port side, the pilot requires a flood tide. This requirement prevents inbound TOTE vessels from achieving additional reductions in average delays beyond -11.5 m MLLW. TOTE outbound vessels are not impacted by the flood tide requirement.

In the without-project condition, the TOTE vessels reduce speed for 3.5 hours before crossing the shoal. On the return trips, the TOTE vessels wait an average of 0.1 hour. If the vessels are behind schedule, the captain will increase speed later to make up for the lost time waiting to depart the Port of Anchorage. With a project, time would be added to the return trip, allowing the vessel to travel more slowly back to the Port of Tacoma. The vessels thus would spend more time at sea but burn less fuel per hour.

In table B-14, the change in average hours at reduced speed is added to the planned trip length to yield a new trip length in hours. A fuel consumption rate and the open-sea inbound fuel consumption, per trip, is then calculated. The shippers stated that with a shoal channel, each ship would travel at a slower speed over the whole trip, enabling the ships to burn less fuel.

TABLE B-14.--*TOTE trip lengths in hours, Tacoma-lower Cook Inlet, and open-ocean fuel use with channels at various depths*

Depth (m)	Planned trip length (h)	Change in avg. hours at reduced speed	New trip length (h)	Distance traveled (km)	Avg. speed (km/h)	Fuel consumption rate (tons/h)	Open-sea fuel consumption per trip (t)
-8.5*	62.5	0.0	62.5	2,589	41.4	6.86	428.8
-11	64.3	1.8	66.1	2,644	40.0	6.18	408.5
-11.5	64.5	2.0	66.5	2,651	39.9	6.11	406.3
-12	64.5	2.0	66.5	2,651	39.9	6.11	406.3
-12.5	64.5	2.0	66.5	2,651	39.9	6.11	406.3
-13	64.5	2.0	66.5	2,651	39.9	6.11	406.3

* Without-project condition.

The vessels would still have to slow down to cross the shoal, but the time spent at reduced speed would be less. Table B-15 shows the amount of fuel TOTE vessels would use in Cook Inlet with a shoal channel at various depths.

TABLE B-15.--*TOTE fuel used in Cook Inlet (lower Cook Inlet-Anchorage) with channels at various depths*

Depth (m)	Avg. hours at reduced speed	Avg. speed (km/h)	Fuel consumption rate (tons/h) at reduced speed	Total fuel used in inlet/trip
-8.5*	3.5	30.6	2.28	8.1
-11	1.7	30.6	2.28	3.9
-11.5	1.5	30.6	2.28	3.5
-12	1.5	30.6	2.28	3.5
-12.5	1.5	30.6	2.28	3.5
-13	1.5	30.6	2.28	3.5

* Without-project condition.

Table B-16 shows total TOTE fuel usage for the trip from Tacoma to Anchorage with a channel at various depths.

TABLE B-16.--*Total fuel used by TOTE vessels, Tacoma-Anchorage, with channels at various depths*

Depth (m)	Fuel used in open sea (t)	Fuel used in Cook Inlet (t)	Total fuel used/trip (t)
-8.5*	428.8	8.1	436.9
-11	408.5	3.9	412.4
-11.5	406.3	3.5	409.8
-12	406.3	3.5	409.8
-12.5	406.3	3.5	409.8
-13	406.3	3.5	409.8

* Without-project condition.

On the return trip to Tacoma, the shippers have to wait to cross the shoal at Anchorage. Table B-17 shows the number of hours the vessels must wait to cross the shoal leaving the Port of Anchorage. (This number would be zero for channel depths of -10 m MLLW and greater.)

TABLE B-17.--*Time TOTE vessels must wait to leave Port of Anchorage, with channels at various depths*

Depth (m)	Hours waiting at port/year	No. of trips	Hours/ trip	Change in waiting time/ trip (h)
-8.5*	12.4	123	0.1	0
-10	0	123	0	-0.1
-11	0	123	0	-0.1
-11.5	0	123	0	-0.1
-12	0	123	0	-0.1
-12.5	0	123	0	-0.1
-13	0	123	0	-0.1

* Without-project condition.

Table B-18 shows the new return trip lengths, calculated by adding the time gained (by not waiting at the Port of Anchorage to cross the shoal) to the planned trip length. This table also shows fuel consumption rates for the return trip with a channel at each depth, and the total fuel used in the open sea per trip.

TABLE B-18.--*TOTE trip lengths in hours, Anchorage-Tacoma, and open-ocean fuel use with channels at various depths*

Depth (m)	Planned trip length (h)	Change in avg. waiting time (h)	New trip length (h)s	Distance traveled (km)	Avg. speed (km/h)	Fuel consumption rate (tons/h)	Open-sea fuel use per trip (t)
-8.5*	65.9	0	65.9	2,697	40.9	6.61	435.6
-11	66.0	0.1	66.1	2,697	40.8	6.55	433.0
-11.5	66.0	0.1	66.1	2,697	40.8	6.55	433.0
-12	66.0	0.1	66.1	2,697	40.8	6.55	433.0
-12.5	66.0	0.1	66.1	2,697	40.8	6.55	433.0
-13	66.0	0.1	66.1	2,697	40.8	6.55	433.0

* Without-project condition.

Table B-19 shows the amount of fuel TOTE vessels would use on the return trip waiting to leave the Port of Anchorage because of the shoal. (This number is zero for channel depths of -11 m MLLW and greater.)

TABLE B-19.--*Fuel TOTE vessels would use waiting to leave the Port of Anchorage, with channels at various depths*

Depth (m)	Hours waiting per trip	Fuel used at port (tons/h)	Fuel used waiting/trip (t)
-8.5*	0.1	0.8	0.1
-11	0	0.8	0.0
-11.5	0	0.8	0.0
-12	0	0.8	0.0
-12.5	0	0.8	0.0
-13	0	0.8	0.0

* Without-project condition.

Table B-20 shows the fuel usage in tons for TOTE vessels on the return trip from Anchorage to Tacoma.

TABLE B-20.--*Total fuel used by TOTE vessels, Anchorage-Tacoma, with channels at various depths*

Depth (m)	Fuel used in open sea (t)	Fuel used waiting to leave port (t)	Total fuel used/trip (t)
-8.5*	435.6	0.1	435.7
-11	433	0.0	433.0
-11.5	433	0.0	433.0
-12	433	0.0	433.0
-12.5	433	0.0	433.0
-13	433	0.0	433.0

* Without-project condition.

Table B-21 shows the total fuel use and total fuel cost savings per year for TOTE with channels at the various depths. The total tons of fuel used per year multiplied by the cost in dollars per ton multiplied by the number of trips gives the change in fuel cost (savings) per year.

TABLE B-21.--*TOTE fuel cost savings per year with channels at various depths*

Depth (m)	Fuel used/year (t) Tacoma/ Anchorage	Anchorage/ Tacoma	Total	Reduction in fuel use (t)	$/ton	No. of trips	Reduction in fuel cost/yr ($)
-8.5*	437	436	873	0	116	123	0
-11	412	433	845	-27	116	123	-388,090
-11.5	410	433	843	-30	116	123	-425,186
-12	410	433	843	-30	116	123	-425,186
-12.5	410	433	843	-30	116	123	-425,186
-13	409	433	843	-30	116	123	-425,186

* Without-project condition.

A channel over Knik Arm Shoal at a depth of -11.5 m MLLW, then, would mean annual fuel cost savings of $425,000 for TOTE. (This number is further refined in the next subsection.)

9.1.3 Fuel Savings Summary.

Reduced Access. Marine pilots for TOTE and Sea-Land have stated that a channel 365 to 457 meters wide would be wide enough that they would not be concerned about grounding when crossing Knik Arm Shoal in any condition of weather or visibility. In the with-project condition, the channel width is 245 m, which is less than what the pilots would prefer. The concerns of the pilots and related reduction of benefits are described below.

Pilots' Concerns. The natural crossing area over the Knik Arm Shoal is 732 meters wide and has a controlling depth of 8.5 m at MLLW for Sea-Land vessels in the without-project condition. The natural crossing area over the shoal is 926 m wide and has a controlling depth of 8.5 m at MLLW for TOTE in the without-project condition. Pilots navigate the vessels across the shoal year-round using two aids to navigation: radar and range lines. (Buoys marking the crest of the Knik Arm Shoal are also used as aids when they are deployed, during the ice-free months of May to October). When the pilots have only one or two navigational aids to use, they are more conservative regarding gross keel clearance over the shoal.

The proposed channel would be 245 m wide. Sea-Land pilots would have their channel reduced by 487 m (732 less 245) when using the excavated channel. TOTE pilots would have their channel reduced by 681 m (926 less 245) when using the excavated channel. The pilots stated that they would not use the dredged channel if they could not use at least two aids to navigation. The only aid the pilots have 100 percent of the time is radar, barring equipment failure. The ranges are invisible in fog, falling snow, or heavy rain. The pilots firmly state that if they can use only radar when crossing the shoal, they would assume the dredged channel did not exist and navigate the shoal as if the controlling depth was 8.5 m at MLLW.

There are three additional factors that might cause the pilots to ignore the dredged channel: high winds, strong currents, and heavy ice. High winds were described as winds greater than 36 km per hour blowing from Turnagain Arm. This wind has an effect on the vessel and how the pilot corrects for the winds when crossing the shoal. Also, strong currents, which routinely exceed 7 meters per second, can cause the vessel to be moved off course when crossing the shoal. With heavy ice conditions the vessels can hit ice pans that can suddenly change the course of the vessel and cause it to move 30 m off course before the pilot can regain control.

Calculation of Benefit Reduction. The Sea-Land and TOTE pilots were unable to give the specific percentage of access that a 245-m-wide channel would provide them. A method of reducing the benefits was devised by applying climatic statistics for the conditions under which pilots said they would not use the channel. One of the conditions was low visibility. Visibility less than 9.3 km (5 nautical miles) when natural tidal depths do not provide adequate keel clearance would cause pilots to wait for a higher stage of the tide. The percentage of time the tides do not exceed the needed draft requirements for the vessels crossing the shoal in the without-project condition was determined.

The visibility data to reduce the percentage access was obtained from the *Climatic Atlas* (Brower *et al.* 1988). The monthly statistics for the year were reviewed for the percentage that visibility was less than 9.3 km at Anchorage.

The pilots stated that if they had poor visibility they would not use the channel but would operate as if the channel did not exist. They would assume a natural shoal elevation of -8.5 m MLLW. A distribution of depths over the shoal was derived from 1 year of hourly predicted tides.

For Sea-Land vessels, the percentage of access was calculated by taking the average draft of the vessel coming to Anchorage, which is 10 m, and adding 3 m for underkeel clearance, which totals 13 m. Figure B-2 shows that this depth is exceeded about 55 percent of the time, which means that 45 percent of the time the depth is insufficient.

For TOTE vessels, the percentage of access was calculated by taking the average draft of the vessel coming to Anchorage, which is 9.1 m, and adding 3 m for underkeel clearance, which totals 12.1 m. Figure B-2 shows that this depth is exceeded about 62.5 percent of the time, which means that 37.5 percent of the time the depth is insufficient. TOTE vessels have an additional complication, however. Because they can dock only on a flood tide, their non-exceedance window must be multiplied by 2, which yields 68.75 percent.

The percentage of reduced access in the with-project condition due to low visibility was computed by multiplying percentage of time with low visibility by the percentage of time

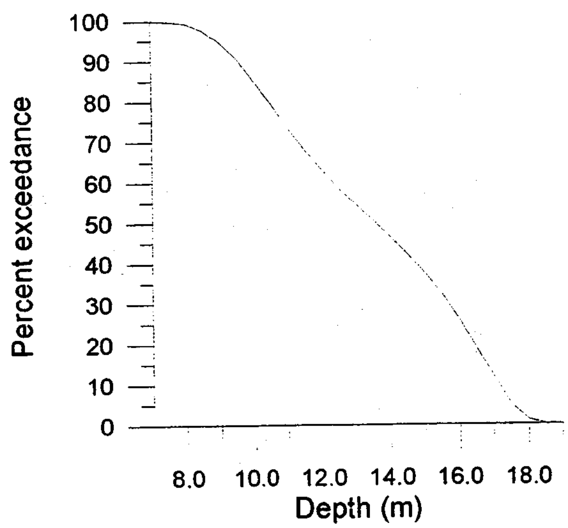

FIGURE B-2.--Percentage of tides exceeding Knik Arm Shoal's natural depth of 8.5 m MLLW at various depths based on 1 year of hourly predicted tides.

when access is constrained at a shoal elevation of -8.5 m MLLW. Fuel benefits would be affected the most by the low visibility, so fuel benefits were reduced by the percentage of reduced access due to low visibility. The total reduced fuel benefit was calculated by multiplying the average monthly fuel benefit by the monthly percentage of access. The 12 months were then totaled to give the yearly reduction in the fuel benefits.

General Summary. The annual fuel cost savings for Sea-Land, then, would be $296,000, less $9,000 for reduced access, for a total of $287,000. The fuel cost benefit for TOTE would be $425,000, less $20,000 for reduced access, for a total of $405,000. The total annual fuel cost savings for both shippers as a result of a -11.5-m-MLLW channel over Knik Arm Shoal would be $692,000.

9.2 Changes in Shoreside Cost

9.2.1 Stevedore Time Use.

Anchorage. Stevedores' compensation structure, as negotiated between the shipping and stevedore companies, plays a significant role in the stevedore costs associated with the tidal delays or arrivals and departure of ships. If the shippers' marine manager calls out stevedores before or after certain times, the shipping companies can incur large labor costs. The shippers prefer to call the stevedores for a 7 a.m. start because it is the least expensive. A start at any other time costs the shippers more in stevedore wages. The ideal time for Sea-Land and TOTE to cross the shoal is between 4 and 5 a.m., depending on the time of year, to be ready to start offloading at 7 a.m.

Stevedore rates are different for Sunday than for the rest of the week. Also, there are six different levels of penalty time for the shippers. Table B-22 shows the basic wage structure of the stevedores' working day. If the stevedores start at 7 a.m., they work the first hour at 1-1/2 times the basic wage. After 8 a.m., they work the next 6 hours at the base wage, or straight time. After that, the stevedores work the rest of the time at 1-1/2 times the base wage. If the stevedores have to work though breaks, shippers pay double time for their present hourly rate. For example, if the stevedores are working at time-and-a-half wages and have to work through a lunch or dinner break, the shippers must pay double time on the time-and-a-half wage. In the with-project condition, shippers would be able to have more 7 a.m. starts and thus pay less overtime.

TABLE B-22.--*Generalized weekday stevedore wage structure for Anchorage, Alaska*

Time period	Wage rate
1 to 5:30 a.m.	Triple time
7 to 8 a.m.	Time and half
8 to 11:30 a.m.	Straight time
1 to 5:30 p.m.	Straight time or time and half
7 to 11:30 p.m.	Time and half

Table B-23 shows the potential change in stevedore costs for Sea-Land and TOTE as a result of the project. The change in the cost is taken as a project benefit. The change in stevedore costs are not uniform over the various depths because the benefits are highly sensitive to the time of day that the vessel arrives at the Port of Anchorage. A difference of an hour can make a large difference in cost if the shipper pays overtime. Sea-Land would not realize any more savings in stevedore overtime costs for a channel at -12.5 m than for a channel at -12 m because the vessel arrival times would not change sufficiently to influence the amount of stevedore labor costs.

A depth of -11.5 m MLLW was chosen as the optimal project depth (see subsection 6.5.3 in the main report for an analysis of channel depth). For a channel at this depth, Sea-Land's annual stevedore savings at Anchorage would be $99,000. TOTE's annual saving would be $278,000. Total stevedore savings at Anchorage would be $377,000.

TABLE B-23.--*Stevedore overtime cost savings at Anchorage ($)*

Depth (m)	Costs for Sea-Land	Reduction in Sea-Land costs	Costs for TOTE	Reduction in TOTE costs
-8.5*	3,850,370	0	5,740,523	0
-11	3,768,977	-81,393	5,467,529	-272,994
-11.5	3,751,729	-98,641	5462,854	-277,669
-12	3,727,847	-122,523	5,460,516	-280,007
-12.5	3,727,847	-122,523	5,460,516	-280,007
-13	3,723,867	-126,503	5,460,516	-280,007

* Without-project condition.

Tacoma. The time spent waiting for tide at Knik Arm Shoal impacts the ships' schedules and thus increases the labor costs necessary to load the vessels not only in Anchorage but also in Tacoma, Washington.

Sea-Land. When Sea-Land vessels are behind schedule, the shippers try to gain time in Tacoma. This is done by using extra stevedores and cranes about 10 percent of the time. Sea-Land normally uses three cranes. If the Sea-Land vessels are behind schedule, the company adds two more cranes to unload and load the vessel faster. The cost of the extra cranes and stevedores averages $8,000 per event.

TOTE. TOTE's vessels use roll-on/roll-off trailers. Loading is accomplished by using stevedores and trucks placed on the vessel. It is impossible to increase the loading rate by increasing the number of stevedores and trucks on the vessel. There is no more room on the vessel for additional vehicles or stevedores. However, a shoal channel can bring a reduction in TOTE's labor cost. Shoal-induced delays result in increased labor costs for TOTE. Stevedores cannot be forced to start work any later than 6 p.m. and cannot work longer than 8 hours. If a crew of stevedores is hired to work from 6 p.m. to 2 a.m. and the vessel does not reach the dock (because of the shoal) until 10 p.m., only 4 hours remain in the stevedore shift. TOTE has to hire a second shift to complete the loading operation. TOTE then pays for 16 hours of labor, even though only 8 are required. In this analysis, only 4 hours have been claimed as a benefit.

Table B-24 shows the benefits of reduced stevedore labor costs at the Port of Tacoma. The total delay was calculated from table B-3 (ship transit simulation model results). The

TABLE B-24.--*Stevedore labor cost savings at Tacoma (costs in $)*

Sea-Land

Depth (m)	Total delay (h)	% of time with no delay	No. of trips	% of time double shift	No. trips delayed because of shoal	Cost per delay	Total cost of delays	Change in cost
-8.5*	410.2	0	102	10	10	8,000	80,000	0
-11	130.1	68	102	10	3	8,000	24,000	56,000
-11.5	79.7	81	102	10	2	8,000	16,000	64,000
-12	37.8	91	102	10	1	8,000	8,000	72,000
-12.5	18.7	95	102	10	1	8,000	8000	72,000
-13	3.9	99	102	10	0	8,000	0	80,000

TOTE

Depth (m)	Total delay (h)	% of time with no delay	No. of trips	% of time double shift	No. trips delayed because of shoal	Cost per delay	Total cost of delays	Change in cost
-8.5*	425.1	0	123	10	12	15,000	180,000	0
-11	204.7	50	123	10	6	15,000	120,000	60,000
-11.5	190.0	54	123	10	6	15,000	90,000	90,000
-12	182.6	55	123	10	5	15,000	90,000	90,000
-12.5	179.8	56	123	10	5	15,000	75,000	105,000
-13	178.4	57	123	10	5	15,000	75,000	105,000

* Without-project condition.

percentage of change was calculated by the difference between the total delay at -8.5 m MLLW (without-project depth) and the total delay at the other alternative depths.

Multiplying the percentage change in delay by the number of trips by the percentage of double shifts gives the number of trips delayed by the shoal. Multiplying the number of trips by the cost of each delay gives the total cost of the delay. The change in the stevedore cost is calculated by subtracting the total cost of delay for the depth in question from the cost in the without-project condition (-8.5 m MLLW).

The annual stevedore labor savings at Tacoma for the optimal project depth of -11.5 m MLLW, then, is estimated at $64,000 for Sea-Land and $90,000 for TOTE, for a total of $154,000.

9.2.2 Stevedores' Time Waiting To Cast Off.

After the stevedores have finished offloading and loading a Sea-Land or TOTE vessel, a crew must stay until the ship leaves to cast the ship off. Both Sea-Land and TOTE ships require eight stevedores to cast off from the dock at Anchorage. The labor rates of the stevedores vary, but most are on at least time-and-a-half or double time. While a ship waits at the dock for a tide window, the stevedores stand idle. When the ship leaves, the stevedores can go home. The project would reduce the time waiting at the dock and reduce the labor input required per trip. The cost of stevedores waiting at the dock is calculated by multiplying the hours waiting at dock by the wage rate by the number of stevedores, to give the total cost of stevedore labor with the project at a certain depth. The change in stevedore cost is the difference between the without-project condition (-8.5 m MLLW) and the depth in question. The change in stevedore labor costs is the cast-off benefit for each depth.

Table B-25 shows that the annual Sea-Land stevedore cast-off savings for a project at -11.5 m MLLW would be $80,000. The savings for TOTE would be $9,000, for a total of $89,000.

TABLE B-25.--*Benefits for avoiding stevedores' idle time waiting to cast off*

Sea-Land

Depth (m)	Hours waiting at dock	Wage/ hour ($)	No. of stevedores	Total cost of stevedore labor ($)	Change in stevedore labor cost ($)
-8.5*	117.9	86	8	81,115	0
-11	17.6	86	8	12,108	-69,007
-11.5	1.3	86	8	12,108	-80,221
-12	0	86	8	0	-81,115
-12.5	0	86	8	0	-81,115
-13	0	86	8	0	-81,115

TOTE

Depth (m)	Hours waiting at dock	Wage/ hour ($)	No. of stevedores	Total cost of stevedore labor ($)	Change in stevedore labor cost ($)
-8.5*	12.4	86	8	8,531	0
-11	0	86	8	0	-8,531
-11.5	0	86	8	0	-8,531
-12	0	86	8	0	-8,531
-12.5	0	86	8	0	-8,531
-13	0	86	8	0	-8,531

* Without-project condition.

9.2.3 Administrative Savings.

Both shippers estimated that they would realize administrative savings from the elimination of disrupted schedules and the consequent need to reschedule with truckers, the railroad, and customers, usually involving overtime labor. With the project in place, it was assumed the time currently spent rescheduling would be used for other administrative labor. Both shippers reported estimates of administrative savings for a project at-11 m MLLW. The savings for other depths were estimated by dividing the savings for -11 m by the change in the hours for -11 m to come up with an hourly rate. The hourly rate was applied to other depths to come up with an estimated savings for each depth. The administration benefit was calculated by subtracting the total delay for each different depth from the total delay for -8.5 m MLLW (without-project condition) to come up with the change in hours. The change in hours was then multiplied by the cost in dollars per hour to give the administrative savings benefit.

The annual administrative savings with a project at.-11.5 m MLLW was estimated at $34,000 for Sea-Land and $53,000 for TOTE, for a total of <u>$89,000</u>. The calculation is shown in table B-26.

TABLE B-26.--*Administrative savings*

Sea-Land

Depth (m)	Total delay (h)	Change in hours	Cost of delay ($/h)	Admin. benefits ($)
-8.5*	292.3	0	102	0
-11	112.5	-280.1	102	29,130
-11.5	78.4	-330.5	102	34,372
-12	37.8	-372.4	102	38,730
-12.5	18.7	-391.5	102	40,716
-13	3.9	-406.3	102	42,255

TOTE

Depth (m)	Total delay (h)	Change in hours	Cost of delay ($/h)	Admin. benefits ($)
-8.5*	437.5	0	215	0
-11	204.7	-232.8	215	50,052
-11.5	190.0	-247.5	215	53,212
-12	182.6	-254.9	215	54,804
-12.5	179.8	-257.7	215	55,405
-13	178.4	-259.1	215	55,707

* Without-project condition.

9.2.4 Container Savings.

With an Anchorage shoal improvement, both shippers estimated they would save money as a result of having fewer containers and trailers parked in the yards at the Port of Anchorage. Both Sea-Land and TOTE often have to leave containers and trailers at the Port of Anchorage so their vessels can leave on the high tide to cross the Knik Arm Shoal. This required surplus of containers and trailers causes the shippers to have to purchase or lease more units. Also, the shippers have to lease more yard space to store the stockpiles. Both shippers estimated their container-related savings for a project at -11 m MLLW. The savings for depths other than -11 m were estimated by dividing the savings for -11 m by the change in the hours for -11 m to come up with an hourly rate. The hourly rate was applied to other depths to yield an estimated savings for each depth. The container benefit was calculated by subtracting total delay hours for each different depth from total delay hours for -8.5 m (without-project condition) to come up with the change in hours. The change in hours was then multiplied by the cost of delay per hour to give the container benefit. These results were verified by Sea-Land and TOTE Alaska marine managers.

The benefit related to container and trailer savings for a channel at -11.5 m MLLW was estimated at $90,000 for Sea-Land and $222,000 for TOTE, for a total of $312,000. The calculation is shown in table B-27.

TABLE B-27.--*Savings related to containers and trailers*

Sea-Land

Channel depth (m)	Reduction in number of trailers used	Cost of trailer per day ($)	Number of days in year	Cost reduction
-8.5*	0	7.5	365	0
-11	28	7.5	365	76,750
-11.5	33	7.5	365	90,338
-12	37	7.5	365	101,288
-12.5	39	7.5	365	106,763
-13	41	7.5	365	112,238

TOTE

Channel depth (m)	Reduction in number of trailers used	Cost of trailer per day ($)	Number of days in year	Cost reduction
-8.5*	0	7.5	365	0
-11	77	7.5	365	210,788
-11.5	81	7.5	365	221,738
-12	85	7.5	365	232,688
-12.5	86	7.5	365	235,425
-13	86	7.5	365	235,425

* Without-project condition.

9.2.5 Insurance Reduction.

TOTE reported an expected reduction of $50,000 annually in insurance premiums. TOTE's Risk Management Department based this reduction on the with-project condition. They felt risk would be reduced in three areas. First, there would be a reduction in risk of grounding a vessel traveling over the shoal. Second, there would be a reduction in risk of collision with another vessel navigating the shoal. Third, there would be a reduction in risk of grounding a vessel while anchored on the north side of the shoal. This takes place when an ebb tide prevents the vessel from docking, forcing it to anchor on the north side. The risk would be reduced because the vessel would be able to travel to the south side of the shoal. The $50,000 in annual benefits did not vary with the channel depth, as long as the channel was surveyed frequently.

9.2.6 Wharfage Savings.

The marine manager of TOTE reports that the company's wharfage fee would decrease under the with-project condition because TOTE would spend less time at the Port of Anchorage. The Port of Anchorage charges the shippers around $700 for every 12 hours a vessel is moored at the dock. The simulation model runs were examined for Sea-Land

and TOTE to identify any change in time spent at the Port of Anchorage. Sea-Land would not be able to spend less than 12 hours in port regardless of channel depth; however, TOTE would be able to spend fewer 12-hour blocks at the Port of Anchorage. Table B-28 shows the benefit for reduced wharfage fees. The benefit is calculated by multiplying the change in number of moorages of less than 12 hours in a year by the wharfage fee. The wharfage savings comes to $9,000.

TABLE B-28.--*Wharfage fee savings (TOTE)*

Depth (m)	No. moorages <12 h in year	Change	Wharfage fee ($)	Benefit ($)
-8.5*	51	0	700	0
-11	39	-12	700	8,400
-11.5	39	-12	700	8,400
-12	38	-13	700	9,100
-12.5	38	-13	700	9,100
-13	38	-13	700	9,100

* Without-project condition.

9.3 Total Estimated Savings

Table B-29 summarizes the benefit categories and total benefits for each channel depth under consideration. The total annual benefits of a navigation channel over Knik Arm Shoal at a safe-navigation depth of -11.5 m MLLW, the optimum depth, are estimated at $654,000 for Sea-Land and $1,115,000 for TOTE. The sum of these benefits is $1,769,000.

TABLE B-29.--*Total annual transportation savings ($)*

Sea-Land

Item	Channel depth (m MLLW) -11	-11.5	-12	-12.5	-13
Fuel savings	237,000	287,000	306,000	316,000	346,000
Stevedore savings, Anchorage	81,000	99,000	123,000	123,000	127,000
Stevedore savings, Tacoma	56,000	64,000	72,000	72,000	80,000
Stevedore castoff savings	69,000	80,000	81,000	81,000	81,000
Administrative savings	29,000	34,000	39,000	41,000	42,000
Container-related savings	77,000	90,000	101,000	107,000	112,000
TOTAL SEA-LAND	549,000	654,000	722,000	740,000	788,000

TOTE

Item	Channel depth (m MLLW) -11	-11.5	-12	-12.5	-13
Fuel savings	370,000	405,000	405,000	405,000	405,000
Stevedore savings, Anchorage	273,000	278,000	280,000	280,000	280,000
Stevedore savings, Tacoma	90,000	90,000	105,000	105,000	105,000
Stevedore castoff savings	9,000	9,000	9,000	9,000	9,000
Administrative savings	50,000	53,000	55,000	55,000	56,000
Container-related savings	211,000	222,000	233,000	235,000	235,000
Insurance savings	50,000	50,000	50,000	50,000	50,000
Wharfage savings	8,000	8,000	9,000	9,000	9,000
TOTAL TOTE	1,061,000	1,115,000	1,146,000	1,148,000	1,149,000
GRAND TOTAL	1,610,000	1,769,000	1,868,000	1,888,000	1,937,000

10. PROJECT COST

Table B-30 summarizes the project cost and annual cost of channels at the various depths with no maintenance dredging.

TABLE B-30.--*Project cost and annual cost ($)*

Item	Channel depth (m MLLW) -11	-11.5	-12	-12.5	-13
First cost	3,948,000	5,036,00	6,222,000	7,661,000	9,268,000
Interest during construction*	64,000	82,000	101,000	124,000	150,000
Total first cost	4,012,000	5,118,000	6,323,000	7,785,000	9,418,000
Average annual cost	319,000	406,000	502,000	618,000	748,000

* Five months for construction + 4 months for Planning, Engineering, & Design (PED) = 9 months at 7-3/4% interest. Level monthly expenditures were assumed.

11. PROJECT SENSITIVITY TO NEED FOR MAINTENANCE DREDGING

A 5-year maintenance cycle is predicted (see appendix A, part 1). Other maintenance schedules were examined as a sensitivity test of project feasibility and depth of optimization. Table B-31 shows the average annual cost, average annual benefits, benefit/cost ratio, and net benefits for each alternative channel depth with maintenance dredging frequencies of 10 years, 5 years, and 2 years.

12. CHANNEL WIDTH SENSITIVITY

Three channel widths were evaluated during the study: 180 m, 245 m, and 310 m. Each channel has a percentage of access related to its width. All the channel depths were evaluated at -11.5 m MLLW. The natural depth of the Knik Arm Shoal is -8.5 m MLLW. The marine pilots use three aids to navigation when crossing the shoal: radar, visual range lines, and buoys. The buoys mark the shoal crest during the ice-free months of May through October. When the pilots have only one or two navigation aids, they are more conservative regarding crossing the Knik Arm Shoal inside a narrower channel. The pilots become more conservative by waiting for a higher tide level to cross the shoal.

The vessel pilots stated they would not use a 180-m channel during the winter months, from November through April (6 months). The pilots would navigate the channel as if it was at -8.5 m MLLW when ice is present. Neither would the pilots use the channel when visibility is less than 5 nautical miles (9.3 km), because they would be limited to only one or two aids to navigation. The pilots would use the 180-m channel approximately 50 percent of the time by ignoring its presence during winter months and times of low visibility.

TABLE B-31.--*Project economic feasibility with various maintenance dredging schedules (costs and benefits in $)*

Maintenance dredging interval	Item	Channel depth (m MLLW) -11	-11.5	-12	-12.5	-13
10 years	Avg. annual cost	319,000	406,000	$502,000	618,000	748,000
	Surveys & maintenance	94,000	106,000	120,000	138,000	152,000
	Total annual cost	413,000	512,000	622,000	756,000	900,000
	Avg. annual benefits	1,610,000	1,769,000	1,868,000	1,888,000	1,937,000
	Net benefits	1,197,000	1,257,000	1,246,000	1,132,000	1,037,000
	Benefit/cost ratio	3.9	3.5	3.0	2.5	2.2
5 years	Avg. annual cost	319,000	406,000	502,000	618,000	748,000
	Surveys & maintenance	235,000	264,000	298,000	344,000	379,000
	Total annual cost	554,000	670,000	800,000	962,000	1,127,000
	Avg. annual benefits	1,610,000	1,769,000	1,868,000	1,888,000	1,937,000
	Net benefits	1,056,000	1,099,000	1,068,000	926,000	810,000
	Benefit/cost ratio	2.9	2.6	2.3	2.0	1.7
2 years	Avg. annual cost	319,000	406,000	502,000	618,000	748,000
	Surveys & maintenance	665,000	747,000	843,000	973,000	1,073,000
	Total annual cost	984,000	1,153,000	1,345,000	1,591,000	1,821,000
	Avg. annual benefits	1,610,000	1,769,000	1,868,000	1,888,000	1,937,000
	Net benefits	620,000	616,000	523,000	297,000	116,000
	Benefit/cost ratio	1.6	1.5	1.4	1.2	1.1

The vessel pilots state they would not use a 245-m channel in ice at low tide when visibility is less than 5 nmi because they cannot use the visual range lines. If pilots cannot use the range lines, they become conservative crossing the shoal and cross with a controlling depth of -8.5 m MLLW. The vessels would use the channel approximately 95 percent of the time.

The vessel pilots stated they would use the 310-m channel most of the time. There would be times that the pilots would not use the channel, for example, during high winds or at times of heavy ice. The pilots would then choose to cross the shoal with a controlling depth of -8.5 m MLLW. This would not happen on a regular basis. The 310-m channel would provide the shippers with nearly 100 percent access (width-wise) when crossing the shoal.

To evaluate the benefits of the 180-m and 245-m channels, they were compared against the 310-m channel that would provide near-total access (width-wise) to the shippers. The benefits of the 180-m channel were calculated by reducing the 310-m channel benefits by approximately 50 percent based on channel access. The benefits of the 245-m channel were calculated by reducing the 310-m fuel benefits by approximately 5 percent. Only the fuel benefits were reduced, because fuel was the most sensitive to channel width access at 245 m.

The benefits, benefit/cost ratios and net benefits of Knik Arm Shoal channels at widths of 180 m, 245 m, and 310 m are presented in table B-32. (As explained in the main report and in appendix A part 1, an excavated width of 305 m is needed to achieve a "pilots' width" of 245 m.)

TABLE B-32.--*Project width alternatives (costs and benefits in $)*

	Channel widths (m)		
	180	**245**	**310**
First cost	3,700,000	5,036,000	5,700,000
Interest during construction	60,000	82,000	92,000
Total first cost	3,760,000	5,118,000	5,792,000
Average annual cost	299,000	406,000	460,000
Surveys & maintenance	220,000	264,000	288,000
Total average annual cost	519,000	670,000	748,000
Benefits	886,000	1,769,000	1,798,000
B/C ratio	1.7	2.6	2.4
Net benefits	367,000	1,099,000	1,050,000

13. CONCLUSION

A navigation channel to reduce the Knik Arm Shoal obstruction before the Port of Anchorage was found to be in the Federal interest. The optimum depth from an economic standpoint would allow a safe clearance at -11.5 m MLLW with a 5-year maintenance cycle. (As explained in appendix A, part 1, an excavated depth of -13.0 m MLLW is necessary to give a safe navigation depth of -11.5 m.) Economic feasibility was found to be unaffected by the uncertainty associated with the channel maintenance cost.

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NAVIGATION IMPROVEMENT AT KNIK ARM SHOAL
COOK INLET, ALASKA

APPENDIX C
SHIP TRANSIT SIMULATION

CONTENTS

Page

TABLES

Table No. Page

CONTENTS--Continued

FIGURES

Figure No. Page

NAVIGATION IMPROVEMENT AT KNIK ARM SHOAL COOK INLET, ALASKA

APPENDIX C SHIP TRANSIT SIMULATION

Introduction

The Cook Inlet Navigation Reconnaissance Study, begun by the Alaska District, U.S. Army Corps of Engineers, in November 1991, was tasked to quantitatively assess the delays and inconvenience suffered by deep-draft vessels due to a series of shoals in upper Cook Inlet. Ships with drafts greater than 15 feet have always had to wait for higher stages of the tide to cross Knik Arm Shoal, 6 miles southwest of Anchorage. Ships with drafts greater than about 25 feet cannot cross Fire Island Shoal, 3 miles west of Fire Island and 15 miles southwest of Anchorage, at extreme low water levels. No accidents occur and no queues form at these shoals because pilots have for decades planned their approaches into upper Cook Inlet to avoid any discrete wait for the tide. Pilots of ships nearing Cook Inlet from the Gulf of Alaska (figure C-1) slow their vessels in lower Cook Inlet to meet high tide at the shoals in upper Cook Inlet. The delays associated with tidal access to points beyond the shoals are therefore difficult to assess, since pilots subjectively choose when, how much, and for how long to slow their ships.

The basic objective of the Cook Inlet Navigation Reconnaissance Study was to evaluate the economic feasibility of channel improvements that would prevent some or all of the delays due to the shoals. Previous studies have made broad assumptions regarding the delays suffered by ships in average tidal conditions. These studies did not find any feasible channel alternatives. Cook Inlet tides are highly variable on several time scales; therefore, so are shipping delays. Previous studies may have underestimated the effect of this variability on vessel delays and the related cost of shipping. The Cook Inlet Navigation Reconnaissance Study sought to account for tidal variability and to accurately estimate the extra ship time spent to safely navigate the shoals in upper Cook Inlet.

The advice of Port of Anchorage officials, shippers, and pilots was gathered in a series of coordination meetings sponsored by the Corps of Engineers. This advice was applied to formulate a time-and-motion numerical model, which simulates the tides of Cook Inlet, the approach of individual vessels, the decisions of pilots navigating Cook Inlet to Anchorage, and the effect of those decisions on vessel arrival and departure times. Delays departing the Anchorage area also occur. Therefore, it was also necessary to simulate the time for berthing maneuvers, the port's daily work schedule, and the progress of offloading and loading the vessels. Records of actual arrival and departure times for the calendar year 1991 were provided by the Port of Anchorage. Ship owners and operators provided vessel-specific

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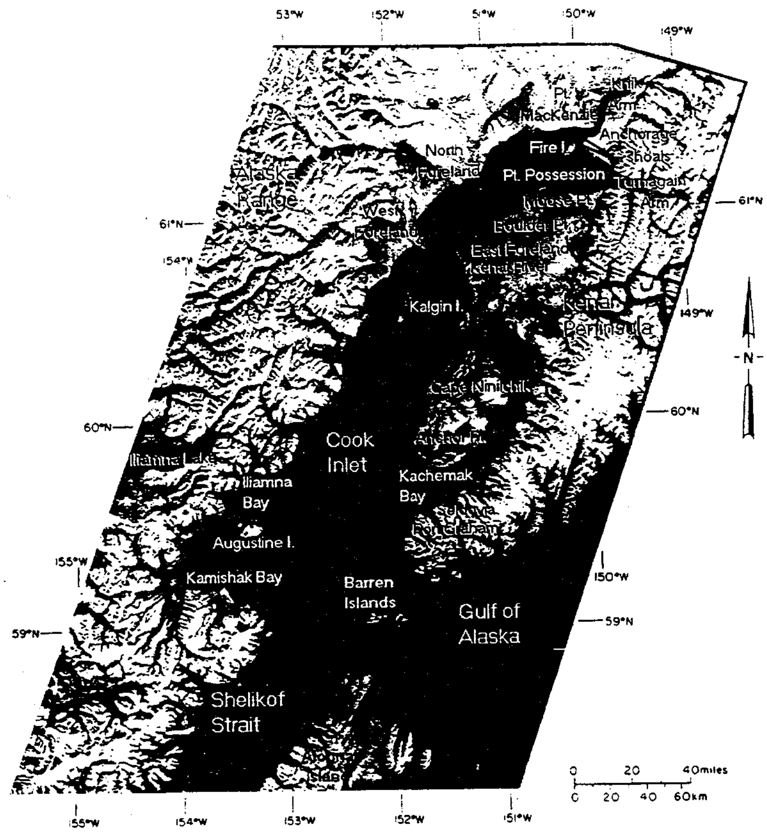

COOK INLET, ALASKA, AND VICINITY

US Army Corps of Engineers Alaska District	COOK INLET NAVIGATION	**C-1**

geometries and operating characteristics, and trip-specific Anchorage-bound departures from the port-of-origin and cargo data. In interviews, Cook Inlet pilots explained what they typically consider when scheduling vessel courses and speeds to navigate up Cook Inlet toward the shoals. The numerical model was formulated to simulate these historical conditions and practical considerations.

Components of the Program Code

The program is modular in its approach to simulating various aspects of conditions in Cook Inlet and transits of Cook Inlet by individual ships. A main program calls on a set of six principal subroutines to accomplish the numerical simulations, as indicated in figure C-2. The assumptions and program actions of the main program and the subroutines are described in the following paragraphs.

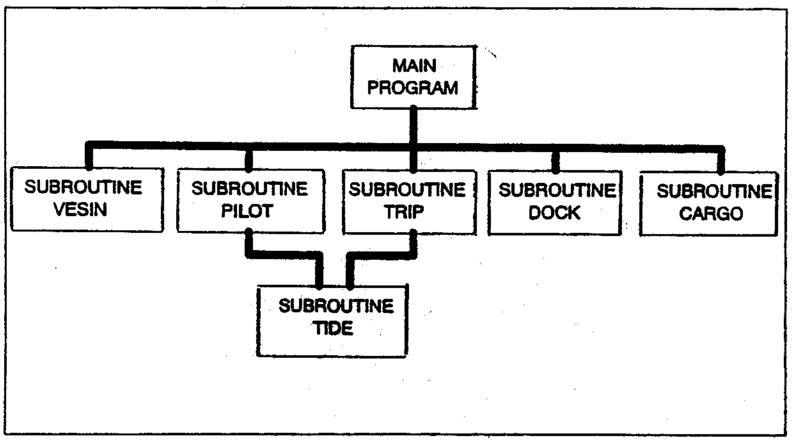

FIGURE C-2.–Schematic of program organization.

The Main Program

The main program specifies the variables used by the program and calls on the subroutines for computations. The only other actions of the main program are to sum the increments of time in each voyage, and to write the output files. Two output files are created for each simulation. An example excerpt from the first output file "transit.txt" is shown in table C-1. This file accumulates values of selected variables which document the progress of each simulated voyage. The first column is the arrival number, which either matches historical records of the Port of Anchorage or includes hypothetical arrivals of vessels which may cross the shoals in the future. Log ships and coal carriers are the two main types of arrivals which were simulated to assess the effect of shoals on possible future traffic in Cook Inlet. The output file "transit.txt" also presents the name of each vessel, its historical (and simulated) time of departure from its port-of-origin in julian days (numbered 0 to 365), its historical time of arrival in Anchorage, its historical time of departure from Anchorage, the distance from Anchorage to the port-of-origin, the cargo amount in trailer equivalent units (TEU) and the rate of cargo transfer in units per hour.

An example excerpt from the second output file, "trandata.txt", is shown in table C-2. This file accumulates key simulation results that correspond to the variables in "transit.txt". The arrival number and ship name are followed by the simulated arrival time in Anchorage, the simulated departure time from Anchorage, the simulated time to discharge cargo, the simulated time spent waiting for the work force to begin offloading and loading, the difference between arrival at full speed and simulated slow speed, and the simulated time waiting for high tide to depart. A summary line is printed at the last of this file including the total number of ship arrivals simulated, the sum of total "slow" times and total "wait" times, the total slow time, the total wait time, the total "work force" time, and the total "cargo" (offloading and loading) time.

TABLE C-1.--*Excerpt from an example "transit.txt" output file*

Trip	Ship	Origin	Arrive	Leave	Distance	FEU	Rate
1	Greatland	3.083	6.083	7.083	1456	700	61
2	Westward V	5.083	8.083	9.083	1456	700	61
3	Greatland	10.083	13.083	14.083	1456	700	61
4	Westward V	12.083	15.083	16.083	1456	700	61
5	Greatland	17.083	20.083	21.083	1456	700	61
6	Westward V	19.083	22.083	23.083	1456	700	61
7	Greatland	24.083	27.083	28.083	1456	700	61
8	Westward V	26.083	29.083	30.083	1456	700	61
9	Greatland	31.083	34.083	35.083	1456	700	61
10	Westward V	33.083	36.083	37.083	1456	700	61
11	Greatland	38.083	41.083	42.083	1456	700	61

TABLE C-2.--*Excerpt from an example "trandata.txt" output file*

Trip	Ship	Arrive	Leave	Cargo	Tide	Slow	Wait
301	Anchorage	6.413	6.969	13.3	0	5.1	0
302	Kodiak	8.47	9.026	13.3	0	6.3	0
303	Tacoma	13.206	14.116	13.3	2.1	0	6.4
304	Anchorage	15.267	15.848	13.3	0.6	1.6	0
305	Kodiak	20.326	20.883	13.3	0	3.1	0
306	Tacoma	22.409	22.966	13.3	0	5	0
307	Anchorage	27.213	28.086	13.3	1.9	0	5.7
.							
.							
.							

Total	Delay	Slow	Wait	Workforce	Cargo
225	847.7	717.4	130.3	289.9	2790

Subroutine VESIN

This subroutine handles the input of vessel and trip variables which identify and specify the controlling parameters of an individual sea voyage. An input file of trip variables is specified interactively by the user, which includes data as illustrated in table C-3. The variables of table C-3 are defined after the table.

TABLE C-3.--*Excerpt from sample input data for individual vessel trips*

TRIP	VID	SHIP	VPORT	VLEFT	VPTIME	VDHERE	VDHIME	VDPRT	VDTIME	VDIST	VFEU	VCTON	VDVTON	VCRGRT
301	1	Anchorage	Tacoma	3	200	6	600	6	2100	1456	961	3300	7300	72
302	1	Kodiak	Tacoma	5	200	8	600	8	2100	1456	961	4800	8860	72
303	1	Tacoma	Tacoma	10	200	13	600	13	2100	1456	961	3300	7300	72
304	1	Anchorage	Tacoma	12	200	15	600	15	2100	1456	961	4800	8860	72
305	1	Kodiak	Tacoma	17	200	20	600	20	2100	1456	961	3300	7300	72
306	1	Tacoma	Tacoma	19	200	22	600	22	2100	1456	961	4800	8860	72
307	1	Anchorage	Tacoma	24	200	27	600	27	2100	1456	961	3300	7300	72
308	1	Kodiak	Tacoma	26	200	29	600	29	2100	1456	961	4800	8860	72
309	1	Tacoma	Tacoma	31	200	34	600	34	2100	1456	961	3300	7300	72
310	1	Anchorage	Tacoma	33	200	36	600	36	2100	1456	961	4800	8860	72
311	1	Kodiak	Tacoma	38	200	41	600	41	2100	1456	961	3300	7300	72
312	1	Tacoma	Tacoma	40	200	43	600	43	2100	1456	961	4800	8860	72
313	1	Anchorage	Tacoma	45	200	48	600	48	2100	1456	961	3300	7300	72
314	1	Kodiak	Tacoma	47	200	50	600	50	2100	1456	961	4800	8860	72
315	1	Tacoma	Tacoma	52	200	55	600	55	2100	1456	961	3300	7300	72
316	1	Anchorage	Tacoma	54	200	57	600	57	2100	1456	961	4800	8860	72
317	1	Kodiak	Tacoma	59	200	62	600	62	2100	1456	961	3300	7300	72
318	1	Tacoma	Tacoma	61	200	64	600	64	2100	1456	961	4800	8860	72

TRIP	Vessel arrival sequence, from the Port of Anchorage's records.
VID	A ship identification number
SHIP	The registered name of the vessel (or an abbreviation)
VPORT	The port-of-origin from which the vessel departed for Anchorage
VLEFT	Date (julian date) of departure from port-of-origin
VPTIME	Time (24 hour clock) of departure from port-of-origin
VDHERE	Actual arrival (julian) date
VDHIME	Actual arrival time (24 hour clock)
VDPRT	Actual departure (julian) date from Anchorage
VDTIME	Actual departure time (24 hour clock) from Anchorage
VDIST	Distance in nautical miles from Anchorage to port of origin
VFEU	Cargo in trailer equivalent units
VCTON	Cargo in tons loaded at Anchorage
VDVTON	Cargo in tons discharged at Anchorage
VCRGRT	Transfer rate for cargo in units per hour

The subroutine VESIN also reads vessel-specific data from an input file "ship2.txt". Vessel draft and other ship characteristics are specified in "ship2.txt". Table C-4 shows the vessel data applied in the Cook Inlet simulations. The variables of "ship2.txt" are defined below.

SHIPID	Equal to "VID", a matching ship identification number
LINE	Name of the shipping line which operates the vessel
VBEAM	The vessel beam, or maximum width, in feet
VLNGTH	The vessel length, overall, in feet
SBERTH	A code related to berthing requirements = 3: vessel needs flood tide to berth = 4: ship's crew unloads & loads the ship (e.g. for tankers) = 1, 2, 5, ...: not used at present
STL(1)	Equal to VLDRFT: ship's loaded draft in feet
STL(2)	Equal to VDRAFT: ship's light (empty) draft in feet
STL(3)	Equal to VEXTRA: keel clearance required (nominally = 10 ft)
STL(4)	Equal to VNORM: ship's fully loaded cargo capacity
STL(5)	Equal to VSPEED: ship's normal open sea cruising speed
STL(6)	Equal to VTLIM: time step (julian days) for simulating trip
STL(7)	Equal to VWORK: time in % per day longshoremen available
STL(8)	Equal to VTHERE: time needed to berth ship
STL(9)	Equal to VLEAVE: time needed to cast off and get underway
VCOST(1)[1]	Equal to VCRCOST: fuel used at cruise speed
VCOST(2)	Equal to VBERCOST fuel used at port
VCOST(3)	Equal to VMAINCOST: fuel price for main engine
VCOST(4)	Equal to VAUXCOST: fuel price for auxiliary engine
VCOST(5)	Equal to VHP: ship horsepower (main engine)
VCOST(6)	Equal to VCREW: number of crew members
VCOST(7)	Equal to VFIXCOST: daily ship fixed cost
VCOST(8)	Equal to VDWT: ship dead weight tons
VCOST(9)	Equal to VGNT: ship gross net tons

[1] VCOST variables were not applied in simulations for the Cook Inlet Navigation Reconnaissance Study. Vessel operating costs were instead applied externally to translate estimated ship delays in hours to equivalent transportation costs.

TABLE C-4.--*Ship data applied in Cook Inlet ship transit simulations*

					STL									VCOST								
SHIPID	LINE	VBEAM	VLENGTH	SBERTH	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1	Sealand	78	710	0	34.33	27.42	10	10500	19.5	0.02	1	0.03	0.025	41.2	2.5	104.9	203.2	20280	21	42484	20817	20965
2	TOTE	105	790	3	29	22	10	9400	22	0.02	1	0.03	0.025	105	10.5	101.5	101.5	30000	29	37850	15500	17637
3	Chevron	96	651	4	36.67	29	10	250000	13.5	0.04	1	0.03	0.025	50	5	101.5	0	12500	21	35000	39000	16941
4	ABI	83	524	4	33.5	19	10	22300	13.5	0.04	1	0.03	0.025	32.3	2	101.5	104.9	11000	0	21020	25402	14921
5	ABI	79	501	4	31.67	18.5	10	19400	13.5	0.04	1	0.03	0.025	30	2	101.5	104.9	10000	0	19500	21340	12905
6	Crowley	100	400	4	20	3	10	132500	8	0.04	1	0.03	0.025	21.5	0.5	104.9	104.9	7200	9	14500	18300	8166
7	Crowley	80	300	4	23	3.5	10	14188	8	0.04	1	0.03	0.025	21.5	0.5	104.9	104.9	7200	8	11020	13122	5498
8	Crowley	74	328	4	16.83	4.5	10	15140	8	0.04	1	0.03	0.025	17.2	0.5	104.9	104.9	6000	8	9410	7910	5058
9	Crowley	46	160	4	7.17	2.08	10	2539	8	0.04	1	0.03	0.025	13.1	0.3	104.9	104.9	2000	8	5220	1400	569
10	0Crowley	80	398	4	19	3	10	11986	9	0.04	1	0.03	0.025	21.5	0.5	104.9	104.9	7200	9	11800	12185	10127
11	Del West	78	282	4	14.67	2.61	10	6834	10	0.04	1	0.03	0.025	12.6	0	104.9	104.9	3600	0	0	6834	3382
12	Del West	78	282	4	14.67	2.61	10	6834	9	0.04	1	0.03	0.025	9.8	0	104.9	104.9	3100	0	0	6834	3365
13	Del West	54	180	4	9.5	2.1	10	1900	5	0.04	1	0.03	0.025	3.9	0	104.9	104.9	1080	0	0	1900	1053
14	Almar	106	600	4	36	16	10	280000	13.5	0.04	1	0.03	0.025	0	0	104.9	104.9	9130	14	0	35080	26351
15	Almar	99	597	4	34.5	10	10	250000	14	0.04	1	0.03	0.025	0	0	104.9	104.9	9244	0	0	36998	25733
16	Almar	80	620	5	27	27	10	1	20	0.02	0	0.03	0.025	0	0	104.9	104.9	24000	325	0	6353	24474
17	Norweg.	98	645	5	28.83	28.83	10	1	19	0.02	0	0.03	0.025	0	0	104.9	104.9	16680	0	0	17224	12834
18	Mapco	0	0	4	0	0	0	1	1	0.02	1	0.03	0.025	0	0	104.9	104.9	0	0	0	0	0
19	Mapco	84	587	4	34.6	22	10	200000	15	0.04	1	0.03	0.025	0	0	104.9	104.9	14000	22	0	27660	17157
20	all Tugs	0	0	0	16	16	10	1	8	0.04	0	0.03	0.025	0	0	104.9	104.9	2000	0	3000	0	0
21	Almar	56	364	5	24	24	10	1	15	0.04	0	0.03	0.025	0	0	104.9	104.9	0	80	0	0	6700
22	Almar	0	0	5	0	0	10	1	8	0.04	0	0.03	0.025	0	0	104.9	104.9	0	0	0	0	0
23	Almar	78	605	4	34	29	10	180000	15	0.04	1	0.03	0.025	0	0	104.9	104.9	15000	20	0	26973	16584
24	Almar	106	600	4	37	20	10	272080	13.5	0.04	1	0.03	0.025	0	0	104.9	104.9	9130	16	0	44999	28258
25	Port Mac	105	745	2	43.3	34.4	10	60000	13	0.04	1	0.03	0.025	43.8	2.5	104.9	104.9	11500	20	13000	60730	32540

Subroutine PILOT

This subroutine simulates the considerations and decisions of a pilot in predicting the time of arrival at Anchorage, making adjustments in vessel speed in lower Cook Inlet so the ship arrives at the shoals with sufficient depth to cross. PILOT also considers the current practice of Totem Ocean Trailer Express (TOTE) roll-on/roll-off vessels (i.e. the M/V *Greatland* and M/V *Westward Venture*) to berth at the Port of Anchorage on a flood tide, so the vessel is maneuvering against the tide during a port-side berthing. A port-side berthing is preferred since the specialized gangway system is designed for the port side of the ship. Decisions regarding passage over the shoals are based on a variable keel clearance requirement. The minimum required depth of water at the shoals, in other words, is the vessel draft plus keel clearance. A keel clearance of 10 feet was applied in simulations for the Cook Inlet Navigation Reconnaissance Study, typical of insurance underwriter requirements for the fleet of commercial vessels now serving Anchorage.

The subroutine PILOT actually becomes active when the simulated position of an approaching ship is 100 nautical miles from the entrance to Cook Inlet. At this point the simulation switches to reduced time steps (of either 1/2 or 1 hour) whose length is associated with the vessel's cruising speed. The subroutine TIDE, which specifies hourly depths and currents at 15 Cook Inlet locations, is called extensively by PILOT to estimate ship arrival time at the shoals. Combinations of reduced vessel speed and duration at reduced speed are simulated in sequence until one combination results in safe passage over the shoals, i.e. the vessel draft plus keel clearance does not exceed the water depth at the shoals at the time of arrival. The trial-and-error process also considers the need for a flood tide berthing, if necessary. A similar process is followed by PILOT when it is called again to plan the ship's departure from the dock.

Subroutine TRIP

Subroutine TRIP accomplishes the actual simulation of the ship's transit of Cook Inlet, computing position versus time for each time step of the journey. The plan developed by PILOT is applied to guide the ship up Cook Inlet toward Anchorage. The trip up Cook Inlet consists of a minimum 15 segments, corresponding to 15 tables of tide heights and currents for segments of Cook Inlet illustrated in figure C-1. The subroutine TIDE is called repeatedly to determine the tidal currents that either oppose or follow a ship in its journey up Cook Inlet. The ship speed over ground is determined by adding the tidal current to the ship's speed through the water. Most simulated journeys involve more than 15 segments, since the specified time step of 1/2 to 1 hour is rarely adequate to allow crossing of all tide-related segments of Cook Inlet in one time step. The journey down the inlet is not simulated through segments beyond the crossing of Fire Island shoal in applications for the Cook Inlet Navigation Reconnaissance Study.

A graphics file is created by TRIP for an optional plot of ship position and ship speed versus time. An example of one ship's simulated transit is presented in figure C-3. This figure illustrates the approach of the Sea-Land vessel M/V *Tacoma* and the simulated pilot decision to slow down in lower Cook Inlet in order to reach Fire Island Shoal and Knik Arm Shoal at

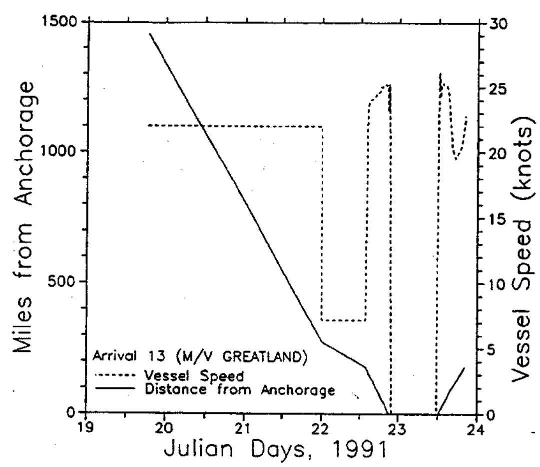

FIGURE C-3.–Sample plot of ship position and speed versus time during a simulated Cook Inlet transit.

high water. The time of zero distance and motion is the time that the ship is at the dock, either waiting for the work day to begin, being unloaded and loaded, or waiting for a high enough tide to depart and cross the shoals outbound. Knik Arm Shoal and Fire Island Shoal are only 6 nautical miles apart, so containerships cruising at 20 knots (kts, nautical miles per hour) cross both shoals in about 20 minutes. Knik Arm Shoal has a controlling depth of -25 ft MLLW and Fire Island Shoal has a controlling depth of -40 ft MLLW over its northern flank. Effectively, pilots need only plan for sufficient high water at Knik Arm Shoal and navigability of Fire Island Shoal is automatically assured.

Subroutine TIDE

The subroutine TIDE reads data from any one of a series of 15 tables of julian date (in fractions at hourly intervals), depth (mean chart depth + predicted tide height above MLLW), and current (positive for flood, negative for ebb). Chart depth is the bottom elevation with respect to MLLW. The subroutine TIDE iterates between table values to estimate the depth and current to within 15 minutes. The tide tables applied in simulations for the Cook Inlet Navigation Reconnaissance Study are based on predicted tides for the calendar year 1991.

Creation of Tide Tables Used by the Subroutine TIDE: The NOAA program "NTP4" was applied to create tabular time series of tide heights and current at 15 locations along Cook Inlet. This program is used by NOAA to prepare the Tide Tables publications published by that agency. The program in its unmodified form prepares tables of the time and height (with respect to MLLW) of high tides and low tides at specific "master stations" along the coast. Two master stations apply to the tides of Cook Inlet: Seldovia, on Kachemak Bay in lower Cook Inlet, and Anchorage, in Knik Arm. The Tide Tables separately print corrections to these times and heights for subordinate stations at coastal locations between master stations. A special version of NTP4 is required for Anchorage because of its exceptionally complex tides. NTP4 predicts tides on the basis of a set of harmonic constituents, or frequency factors which apply at a given geographical location. These constituents are derived by NOAA from tidal records at the master station locations which exceed 19 years in length. The need for such a long record relates to the periods of various astronomical cycles which change the gravitational pull of the sun-earth-moon system. The standard version of NTP4 applies 37 tidal constituents to simulate significant effects on the sea surface of these astronomical cycles. The Anchorage version of NTP4 applies 124 tidal constituents to more accurately simulate the complex tides that occur in Knik Arm.

Both versions of NTP4 were first modified to tabulate the time of tide heights in julian days, rather than the standard month and day format. Another modification allowed automatic incorporation of time and height corrections for any specific subordinate station. The subordinate station corrections applied in the Cook Inlet Navigation Reconnaissance Study, corresponding to segments of Cook Inlet as indicated by figure C-1, are listed in table C-5.

The standard version and Anchorage version of NTP4 have the option of tabulating all hourly tide heights, rather than just the times and heights of high water and low water. This option was not used, even though hourly predictions were necessary for the ship transit simulations. Rather, a smooth half-cycle sinusoidal variation was imposed between each predicted high water and low water, and hourly heights were interpolated along the sinusoidal curve. The exact predicted time and height of high water and low water are retained in the output, whether or not they occur on an even hour.

Zero current was assumed to exist at the time of each high water and low water. Tidal currents were assumed to vary as a function of water surface slope, of depth, and of the roughness of the sea bottom. Stated differently, a balance between friction and inertia was assumed at each point in time. This assumption is not generally valid for tidal flows, but it serves as an expedient way in this application to predict a tidal current for each stage of the tide, given only an average depth and bottom condition at a site. The approach allows adjustment of the friction parameter to "tune" the tidal currents to match representative values published each year by NOAA in Tidal Current Tables. Manning's equation for open-channel flow was applied for this purpose.

TABLE C-5.--*Tidal data applied in the Cook Inlet Navigation Reconnaissance Study*

Location	Latitude	Mean shipping route depth (ft)	Source of correction	Time correction (julian days)		Height correction		Master station
				High water	Low water	High water	Low water	
Barren Islands	58.9450	360	published	-0.0056	-0.0028	x 0.76	x 0.76	Seldovia
Port Graham	59.4667	240	published	-0.0056	-0.0097	-1.0 ft	+0.0 ft	Seldovia
Anchor Point	59.8000	120	published	+0.0201	+0.0146	+0.4 ft	+0.0 ft	Seldovia
Cape Ninilchik	60.0500	120	published	+0.0285	+00375	+1.2 ft	+0.2 ft	Seldovia
Kalgin Island	60.2833	120	interpolated	+0.0532	+0.0666	+2.0 ft	+0.4 ft	Seldovia
Kenai River mouth	60.5500	120	published	+0.0778	+0.0958	+2.7 ft	+0.5 ft	Seldovia
East Foreland	60.7000	90	published	+0.1090	+0.1236	+3.0 ft	+0.5 ft	Seldovia
Boulder Point	60.8500	90	interpolated	+0.1207	+0.1367	+4.2 ft	+0.5 ft	Seldovia
North Foreland	60.9667	90	published	+0.1359	+0.1537	+5.8 ft	+0.5 ft	Seldovia
Moose Point	61.0833	70	interpolated	+0.1485	+0.1685	+7.0 ft	+0.6 ft	Seldovia
Point Possession	61.1500	70	interpolated	+0.1611	+0.1833	+8.2 ft	+0.6 ft	Seldovia
Fire Island Shoal	61.1833	48	interpolated	-0.0217	-0.0242	x 0.92	x 0.92	Anchorage
Race Point	61.1667	70	published	-0.0174	-0.0194	x 0.94	x 0.94	Anchorage
Knik Arm Shoal	61.2000	25	interpolated	-0.0131	-0.0146	x 0.96	x 0.96	Anchorage
Anchorage	61.2333	90	published	0.0	0.0	0.0	0.0	Anchorage

$$U = \frac{1.49}{n} d^{2/3} S^{1/2}, \qquad 1$$

where U = vertically averaged current speed in feet per second
n = Manning's "n" friction factor
d = depth in feet, assuming a wide flow cross-section
S = water surface slope

Comparison of Predicted and Published Current Statistics: The tide current algorithm was adjustable by the Manning's "n" friction factor for matching its current predictions with published representative currents in the NOAA *Tidal Current Tables*. The 1991 tables were consulted for locations along the shipping route in Cook Inlet to Anchorage. Currents are specified by NOAA in terms of "average maximum flood" and "average maximum ebb." The maximum hourly currents predicted by the tidal current algorithm for each phase (flood or ebb) of each tide in the calendar year 1991 were averaged for comparison to tidal current statistics published by NOAA for the nearest location. Manning's "n" was adjusted to create a new tide table for each subordinate station until the predicted average maximum flood current and maximum ebb current (from the hourly currents predicted for 1991) matched as closely as possible to the published values. This method was used for predicting hourly tidal currents at all subordinate stations except the deepest station (360-foot-depth) at the Barren Islands.

Tidal Current Predictions at the Barren Islands: The development of predicted tidal currents based on a quasi-steady balance between inertia, as measured by surface slope, and friction, proved to predict currents close to published values, except at the deeper locations in lower Cook Inlet. The expedient method of adjusting friction appeared not to work for these deep stations where bottom friction has less influence than other factors. An alternative formulation of tidal flows was attempted, based on inviscid plane wave theory. The dispersion relation for shallow water inviscid plane waves at constant depth is:

$$C^2 = \sqrt{C_o^2 + \frac{f^2}{K^2}}, \qquad 2$$

where C = the phase speed, or speed of a wave crest, = L/T,
T = wave period,
C_o = the phase speed of a shallow water linear wave = (gd),
g = the acceleration of gravity,
f = the Coriolis parameter = 2Wsinq,
W = earth's rate of rotation = 7.3 x 10^{-5} sec^{-1},
q = latitude (see Table 5),
K = wave number = 2p/L, and
L = wave length (L >> d).

Water particle velocity, i.e. current speed (u), perpendicular to the crest is:

$$u = \frac{\eta_o}{d} C \cos(Kx - \sigma t + \phi) \ , \qquad 3$$

where h_o = amplitude of the wave,
x = distance before crest,
s = wave frequency = 2p/T, and
f = phase.
Solving for wave length, L,

$$L = 2\pi \sqrt{\frac{gd}{(\frac{2\pi}{T})^2 + f^2}} \ , \qquad 4$$

which can be applied to solve for C, since g, d, T, and f are known. The maximum current is of concern, so Kx - st = 0 and cos(Kx - st) = 1. The maximum current follows high (or low) water by a phase of p/2 (90°). The 360-foot-depth at the Barren Islands yields an estimate of 2.8 knots for maximum current, while Manning's equation predicted over 4 knots. Adjustment at this depth of friction could not bring currents predicted by Manning's equation into a range close to that measured nearby by NOAA. The inviscid shallow water wave estimate is more reliable for this deep open location. Adjustment of Manning's "n" served as an expedient method to predict realistic currents at other shallower stations. It should be noted, however, that the earth's rotation has a significant effect on tidal currents in Cook Inlet, as indicated by the fact that the value of f^2/K^2 is of the same order as C_o^2 in the dispersion relation (equation 2). Future simulations of Cook Inlet ship transits could include more accurate non-linear estimates of tidal currents, but this refinement does not appear to have significant consequences to practical conclusions drawn from simulation results.

Table C-6 shows the comparison for the values applied for creating the tide tables applied in the Cook Inlet Navigation Reconnaissance Study. Values of Manning's "n" all fall within the range of values in general use for irregular sandy bottoms, without much plant growth. Values published by NOAA are intended as representative values for reference by mariners navigating the region and often are the product of only short-term measurements. The specific location, depth, and time of year of short-term measurements could affect the published current values by a knot or more. Likewise, the specific location could affect the difference between the flood and ebb current speeds. Furthermore, the maximum currents reported by NOAA may also be a spatial maximum, rather than a vertical average current, as predicted by Manning's equation. The assumption of sinusoidal variation of water surface elevation between predicted high and low waters and slope-driven currents in the predictions resulted in consistently stronger long-term average flood currents. Higher-order variations in real ebb tides tend to make real ebb current flows stronger.

TABLE C-6.--*Comparison of predicted and NOAA published current statistics*

Tide station	Assumed values		Average maximum currents (knots)			
	Depth (ft)	Manning's "n"	Predicted		Published	
			Flood	Ebb	Flood	Ebb
Barren Islands	360	inviscid estimate	1.2	-1.2	1.6	0.9
Port Graham	240	0.047	2.4	-2.5	-	-
Anchor Point	120	0.037	2.4	-2.5	2.4	-2.5
Cape Ninilchik	120	0.032	3.0	-2.9	2.6	-3.5
Kalgin Island	120	0.033	3.0	-2.8	2.7	-3.3
Kenai River	120	0.029	3.5	-3.3	3.1	-3.6
East Foreland	120	0.028	3.4	-3.2	-	-
Boulder Point	90	0.025	3.8	-3.6	3.4	-4.3
North Foreland	90	0.028	3.5	-3.3	3.4	-3.4
Moose Point	70	0.027	3.5	-3.3	-	-
Point Possession	70	0.026	3.7	-3.5	3.6	-3.8
Fire Island Shoal	48	0.025	3.5	-3.2	-	-
Race Point	70	0.026	3.8	-3.6	-	-
Knik Arm Shoal	25	0.024	3.1	-2.9	2.9	-2.3
Anchorage	90	0.028	4.1	-3.7	3.9	-4.0

Subroutine DOCK

This subroutine provides the simulation of berthing and cast-off maneuvers, with a view toward the particular requirements of each ship. Subroutine DOCK also simulates any wait for the dockside workforce to arrive, either to assist with berthing or to unload, by checking the simulated time of arrival and the time berthing maneuvers are complete with the scheduled start of the workday for longshoremen. The requirements for longshoreman service is also considered for each ship, since some ships, *e.g.*, some liquid bulk carriers, are unloaded by their own crew and require no longshoremen. Time spent waiting for the workforce at the dock is stored in a variable "DTLOST".

Subroutine CARGO

Subroutine cargo deals with offloading and loading the cargo of each ship, as specified in the trip data file, according to its specified individual requirements at the rate specified in the ship data file. This subroutine also keeps track of the daily work schedule at the dock and accounts for cases when cargo is not fully unloaded or loaded in a single work day. This subroutine, on computing the time when a vessel is loaded and ready to leave, starts the clock on tidal delays waiting for high water at the shoals. Subroutines PILOT and TRIP are called in sequence by the main program, for the departure leg when subroutine DOCK has completed its computations.

Results

Verification

The historical 1991 arrival and departure log of the Port of Anchorage was applied to both develop the model and to verify simulated arrival and departure times. The data from the Port of Anchorage log was expanded to include departure dates and times from the ports of origin and detailed characteristics of the ships and cargoes which arrived at Anchorage in 1991. The actual dates and times of departure from the port of origin are input variables for simulated arrivals, as are ship and cargo characteristics. Predicted 1991 Cook Inlet tide heights and currents were tabulated for use in the simulations as discussed previously. These input data result in simulated arrivals at and departures from the Port of Anchorage, which can be compared to the historical arrivals and departures.

Arrivals of loaded containerships provide a thorough test of the model's ability to simulate pilot decisions regarding high tide passage over the shoals. Sea-Land had 101 containership arrivals at the Port of Anchorage in 1991. TOTE had 98 containership arrivals. Differences between predicted and actual arrivals and predicted and actual departures were usually within an hour or two. A less accurate model would miss by one or more high tides, i. e. by 12 hours or more. The human pilot of a real 1991 voyage up Cook Inlet may have chosen to slow the ship by 4 knots for 10 hours, while the model chose to slow the ship by 8 knots for 4 hours. Both the human pilot of the real voyage and the PILOT subroutine chose a plan which will cause the ship to arrive at the shoal at a particular high tide. The rate and duration for slowing the ship which will cause the ship to arrive at high water has many combinations which will be equally successful. The overall duration of the voyage, from the port of origin to the Port of Anchorage, will be affected the same, no matter which successful combination is used.

Figures C-4 to C-7 are scattergrams of simulated and actual arrivals of the 101 Sea-Land 1991 arrivals at the Port of Anchorage. The departures from perfect agreement are indistinguishable at a one year scale. Figure C-8 looks only at Sea-Land arrivals during the icy month of February 1991 and small departures from perfect agreement, i. e. the 45 degree line, can be distinguished. The statistics of the differences between actual and simulated arrivals and departures are more revealing, as presented in table C-7. The mean error of simulations is only 1/2 hour on arrivals, when the major tidal delay occurs for these containerships loaded with import cargo. Larger errors occur, but the arrival error standard deviation of 5.8 hours indicates most simulated arrivals occurred during the same high tide as the actual arrival. The mean departure error was larger, but still less than 6 hours or 1/2 the time between high tides. This mean and the standard deviation of departure errors of 6.3 hours indicate that most of the 199 departures in the sample occurred on the same high tide. The larger errors on departure probably relate to inaccuracies in simulation of cargo transfer rates, the variability of the work shifts, and decisions to depart at high tide with less than a full load.

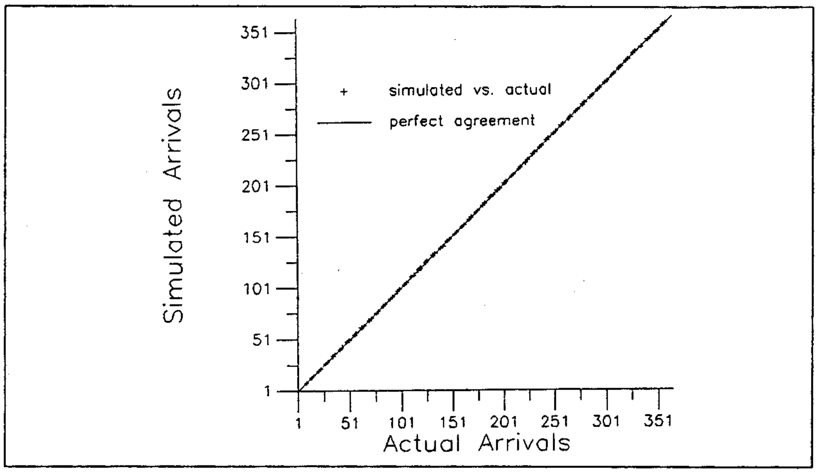

FIGURE C-4.—Simulated versus actual Sea-Land arrivals.

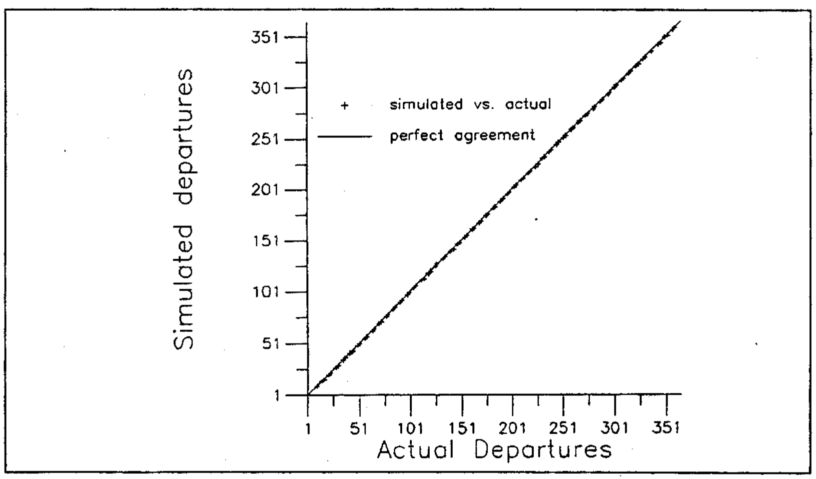

FIGURE C-5.—Simulated versus actual Sea-Land departures.

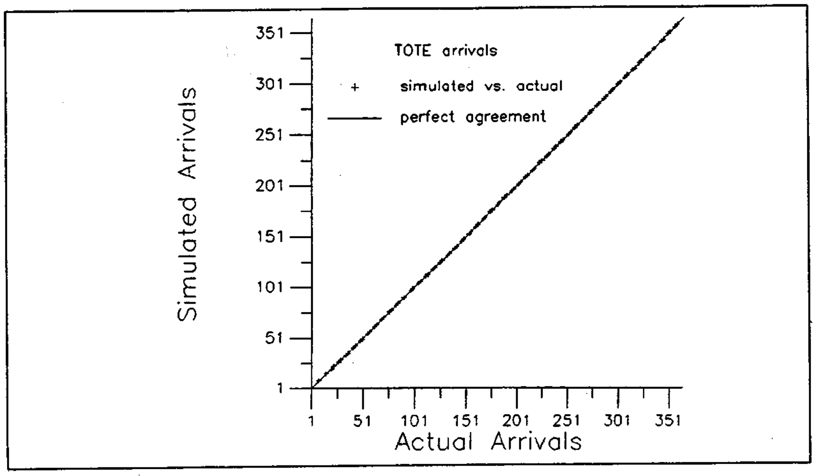

FIGURE C-6.--Simulated versus actual TOTE arrivals.

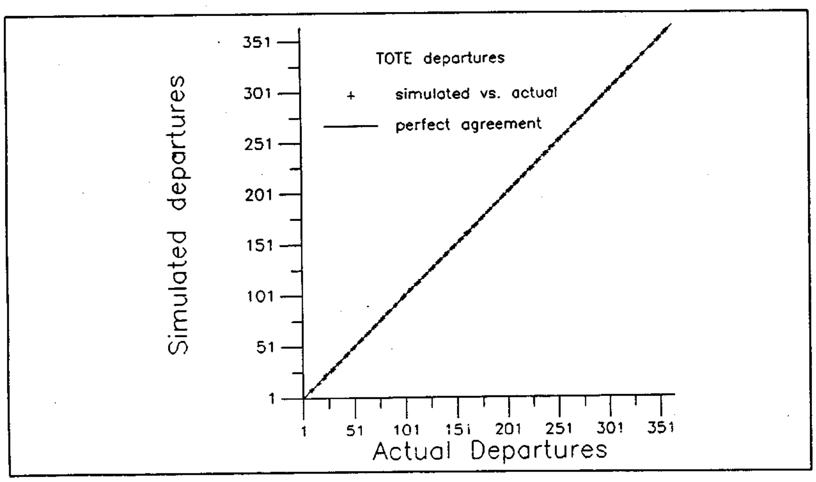

FIGURE C-7.--Simulated versus actual TOTE departures.

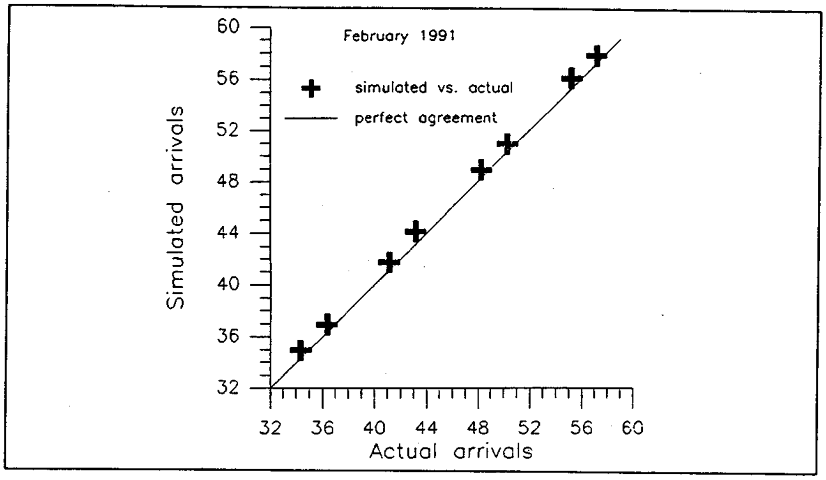

FIGURE C-8.--Simulated versus actual Sea-Land arrivals for February 1991.

TABLE C-7.--*Comparisons of simulated and actual arrivals and departures (hours)*

Results compared	Maximum early simulated result	Maximum late simulated result	Mean difference	Standard deviation
Combined Sea-Land and TOTE arrivals	24.4	32.9	0.5	5.8
Combined Sea-Land and TOTE departures	34.6	22.9	5.7	6.3

Final Adjustments to the Model

The ship transit simulation was developed and first applied in the reconnaissance phase of this study. A number of refinements were incorporated into the model code during the feasibility phase. These included:

a. The weight of trailers on TOTE ships was added to the cargo weight from port records for more precise draft computations.

b. Likewise, the weight of containers on Sea-Land ships was added to the cargo weight from port records.

c. The rates for loading containers and trailers on Sea-Land and TOTE ships were corrected to match more recent information from marine managers of these companies.

d. The cargo capacities in tons for Sea-Land ships were corrected to match more recent information from marine managers.

In response to a comment from reviewers, vessel schedules for both TOTE and Sea-Land are included after the text of this appendix.

Conclusions

The simulated results predict containership arrivals and departures with adequate accuracy for estimation of average delays per vessel and average total delays per year. Containership cargo is projected to continue as the primary traffic into and out of the Port of Anchorage for the foreseeable future. Time savings for this class of vessels will be critical to benefit estimates associated with increased tidal access provided by channel excavation. The simulations, as presently programmed, show potential for only minor refinement, which would have little tangible effect on the average annual benefit computations on which economic feasibility must be based.

TOTEM OCEAN TRAILER EXPRESS, INC
Vessel-Office Correspondence

TO: R. Magee | DATE: November 16, 1995
FROM: R. Griffith
SUBJ: VESSEL SCHEDULE

	NORTHBOUND				SOUTHBOUND			
VOY	ETD TAC		ETA ANC		ETD ANC		ETA TAC	
WV 231	0100	12/21	1800	12/23				
WV 232					1800*	12/24	1700	12/27
GL 233	0300	12/23	0800	12/26				
GL 234					1800*	12/27	1700	12/30
WV 001	0300	12/30	0200	1/2				
WV 002					1800*	1/2	1700	1/5
GL 003	0300	1/4	0600	1/7				
GL 004					1800*	1/7	1700	1/10
WV 005	0300	1/6	0700	1/9				
WV 006					1800*	1/9	1700	1/12
GL 007	0300	1/11	2200	1/13				
GL 008					1800*	1/14	1700	1/17
WV 009	0300	1/13	0000	1/16				
WV 010					1800*	1/16	1700	1/19
GL 011	0300	1/18	0500	1/21				
GL 012					1800*	1/21	1700	1/24
WV 013	0300	1/20	0700	1/23				
WV 014					1800*	1/23	1700	1/26
GL 015	0300	1/25	2200	1/27				
GL 016					1800*	1/28	1700	1/31
WV 017	0300	1/27	0100	1/30				
WV 018					1800*	1/30	1700	2/2
GL 019	0300	2/1	0500	2/4				
GL 020					1800*	2/4	1700	2/7

* To be determined by Anchorage Operations

RWG/rdl

cc: E. Trout, J. Keck, J. Britt, B. King, J. Gauntt,
M. Johnson, Master WV, T. DeBoer, J. Finkel, T. Spielman,
D. Morisseau, Master GL, G. Jackson, K. Rydman, P. Den,
B. Mathisen, Master NL, J. White, L. Shapiro, C. Stephens

ALASKA SERVICE

FEBRUARY/MARCH/APRIL 1995

NORTHBOUND

VOYAGE NUMBER	BOOKING PREFIX	DEPART TACOMA	ARRIVE* ANCHORAGE	ARRIVE KODIAK	ARRIVE DUTCH HARBOR
AZ-258N	843	WED 2-1	SAT 2-5	MON 2-6	
KO-245N	844	FRI 2-3	TUE 2-7	WED 2-8	FRI 2-10
TW-253N	845	WED 2-8	SUN 2-12	MON 2-13	
AZ-259N	846	FRI 2-10	TUE 2-14	WED 2-15	FRI 2-17
KO-246N	847	WED 2-15	SUN 2-19	MON 2-20	
TW-254N	848	FRI 2-17	TUE 2-21	WED 2-22	FRI 2-24
AZ-260N	849	WED 2-22	SUN 2-26	MON 2-27	
KO-247N	850	FRI 2-24	TUE 2-28	WED 3-1	FRI 3-3
TW-255N	851	WED 3-1	SUN 3-5	MON 3-6	
AZ-261N	852	FRI 3-3	TUE 3-7	WED 3-8	FRI 3-10
KO-248N	853	WED 3-8	SUN 3-12	MON 3-13	
TW-256N	854	FRI 3-10	TUE 3-14	WED 3-15	FRI 3-17
AZ-262N	855	WED 3-15	SUN 3-19	MON 3-20	
KO-249N	856	FRI 3-17	TUE 3-21	WED 3-22	FRI 3-24
TW-257N	857	WED 3-22	SUN 3-26	MON 3-27	
AZ-263N	858	FRI 3-24	TUE 3-28	WED 3-29	FRI 3-31
KO-250N	859	WED 3-29	SUN 4-2	MON 4-3	
TW-258N	860	FRI 3-31	TUE 4-4	WED 4-5	FRI 4-7
AZ-264N	861	WED 4-5	SUN 4-9	MON 4-10	
KO-251N	862	FRI 4-7	TUE 4-11	WED 4-12	FRI 4-14
TW-259N	863	WED 4-12	SUN 4-16	MON 4-17	
AZ-265N	864	FRI 4-14	TUE 4-18	WED 4-19	FRI 4-21
KO-252N	865	WED 4-19	SUN 4-23	MON 4-24	
TW-260N	866	FRI 4-21	TUE 4-25	WED 4-26	FRI 4-28
AZ-266N	867	WED 4-26	SUN 4-30	MON 5-1	
KO-253N	868	FRI 4-28	TUE 5-2	WED 5-3	FRI 5-5
TW-261N	869	WED 5-3	SUN 5-7	MON 5-8	

SOUTHBOUND

VOYAGE NUMBER	DEPART ANCHORAGE	DEPART KODIAK	DEPART DUTCH HARBOR	ARRIVE TACOMA
AZ-258S	MON 2-6	TUE 2-7		FRI 2-10
KO-245S	WED 2-8	WED 2-8	SAT 2-11	WED 2-15
TW-253S	MON 2-13	TUE 2-14		FRI 2-17
AZ-259S	WED 2-15	WED 2-15	SAT 2-18	WED 2-22
KO-246S	MON 2-20	TUE 2-21		FRI 2-24
TW-254S	WED 2-22	WED 2-22	SAT 2-25	WED 3-1
AZ-260S	MON 2-27	TUE 2-28		FRI 3-3
KO-247S	WED 3-1	WED 3-1	SAT 3-4	WED 3-8
TW-255S	MON 3-6	TUE 3-7		FRI 3-10
AZ-261S	WED 3-8	WED 3-8	SAT 3-11	WED 3-15
KO-248S	MON 3-13	TUE 3-14		FRI 3-17
TW-256S	WED 3-15	WED 3-15	SAT 3-18	WED 3-22
AZ-262S	MON 3-20	TUE 3-21		FRI 3-24
KO-249S	WED 3-22	WED 3-22	SAT 3-25	WED 3-29
TW-257S	MON 3-27	TUE 3-28		FRI 3-31
AZ-263S	WED 3-29	WED 3-29	SAT 4-1	WED 4-5
KO-250S	MON 4-3	TUE 4-4		FRI 4-7
TW-258S	WED 4-5	WED 4-5	SAT 4-8	WED 4-12
AZ-264S	MON 4-10	TUE 4-11		FRI 4-14
KO-251S	WED 4-12	WED 4-12	SAT 4-15	WED 4-19
TW-259S	MON 4-17	TUE 4-18		FRI 4-21
AZ-265S	WED 4-19	WED 4-19	SAT 4-22	WED 4-26
KO-252S	MON 4-24	TUE 4-25		FRI 4-28
TW-260S	WED 4-26	WED 4-26	SAT 4-29	WED 5-3
AZ-266S	MON 5-1	TUE 5-2		FRI 5-5
KO-253S	WED 5-3	WED 5-3	SAT 5-6	WED 5-10
TW-261S	MON 5-8	TUE 5-9		FRI 5-12

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Seattle	(206) 233-3474

*Start times in Anchorage are planned for 0830 unless otherwise noted.

Wednesday departures now available weekly from Dutch Harbor to Tokyo

Sea-Land

Published: 1/10/95

APPENDIX D
CORRESPONDENCE

Sea-Land

Sea-Land Service, Inc.
World Trade Center—4th Floor
3600 Port of Tacoma Road
Tacoma, Washington 98424
(206) 593-8100

April 4, 1996

Mr. Orsen Smith
Department of the Army
U.S. Army Engineer District, Alaska
P.O. Box 898
Anchorage AK 99506-0898

Subject: Port of Anchorage and the Knik Arm Shoal Removal.

Dear Sir:

Sea-Land Service, Inc. is extremely pleased with the recent progress which has been made to take this project from the realm of discussions, to reality. Sea-Land started its first year around service to the Port of Anchorage in 1964 with the call of the SS Anchorage. It was realized back then that Knik Arm Shoal stood as a major obstacle to developing an unrestricted service to the port. As it stands, Sea-Land vessels are restricted by two daily tidal windows which ensure there is sufficient water to make safe arrivals and departures. These windows, if missed, then impact not only Sea-Land, but the Alaskan customer base and the state. Statistically, these tidal windows prevent Sea-Land from crossing the shoal some 43% of the time. In this day and age, this is totally unacceptable to needs of the ever growing state of Alaska.

Sea-land's commitment to Alaska came when it introduced three D-7 classed vessels with special construction to meet the demands of the area. Each vessel has a re-enforced ice bow which safeguards the ships' transits through the ice flows and packs of Cook Inlet. In the construction of these ships, two thrusters were incorporated to assist in the docking/undocking evolution and giving the ships the ability to flush ice away from between the ship and the dock. Each D-7 , (Sea-Land Anchorage, Sea-Land Kodiak, and Sea-Land Tacoma), has an overall length of 216M, a beam of 23.8M, a deep draft of 9.7M and a service speed of 19.2 knots.

The dredging proposal calls for a channel width of a 180 meters, with an additional excavated area of 30 meters on either side, for channel stability. As discussed in the open forum in December, this is not even close to the original width that was requested by Sea-Land and Tote. This reduced width is unacceptable for transiting, because it does not afford any real safety margin to cope with unique elements which are found in Cook Inlet. A 180 meter channel would be acceptable in others parts of the world , because they do not contend with such dynamic tidal systems, severe ice and wind conditions and a such unforgiving and ever changing topography (rock/boulder bottom)

These natural elements consistently affect our vessel, often forcing them crosswise in the channel. This effect is know as crabbing, forcing the vessel to stem the tide/current/ice to make good the course. No complicated arithmetic is required to show that a 216 meter ship cannot go far before either the bow, stern or both are hard aground with 180 wide channel. Crabbing is a common result of strong cross currents, strong winds, and substantial ice packs which are prevalent to Cook Inlet. Our vessels have been thrown off course by more than 20 degrees when they have encountered ice packs (often measuring 2-3 feet thick and as large as a football field). Even the most cunning of skills in pilots and masters cannot be expected to overcome such a physical phenomena. On top of this, you throw in reduced visibility which is a fact of Cook Inlet, and any prudent operator would find a narrow channel unsafe.

A 305M working channel with the 30 meters excavated area on either side gives a vessel a safe margin to maneuver, and an ability to counter the physical elements of Cook Inlet. Well pointed out in the "Deep Draft Navigation Feasibility Report" of September 1995, the project planners and scientists do not definitively know how or what affects the proposed channel will have on transiting ships. This is, again, because of the uniqueness of Cook Inlet, that cannot be found anywhere else in the world. They fully realize that when all the elements are thrown into the pot, there is a complicated equation to be dealt with. Anyone of these natural phenomena can play havoc with shipping. History well documents that Cook Inlet has taken its toll on shipping from the years of 1964 to 1968 when insufficient margins were considered. Eight (8) vessels grounded during this early period of vessels calling the Port of Anchorage. We should not let these lessons be forgotten in this project.

From the beginning it is necessary to establish adequate parameters which the 305 meter working channel width is, and success will follow.

The insight of this project, its developers and its supporters have put forth a perspective which can provide an unrestricted transportation mainline to the Port of Anchorage and the infrastructure of the state Alaska's growth requires it.

Sincerely,
Sea-Land Service Inc.

Dave Burmeister
Ship Superintendent

DBB/mdh

cc: Elizabeth - G. Moyer - SMS
Anchorage - B. Deaver - SMS
- D Dorsey - SMS

COOK INLET DEEP-DRAFT NAVIGATION PROJECT NEAR ANCHORAGE, ALASKA
ASSESSMENT OF SPONSOR'S FINANCING CAPABILITY

April 2, 1996

The Cook Inlet Deep-Draft Navigation project is proposed for authorization in the Water Resources Development Act of 1996. The Municipality of Anchorage will be the non-Federal sponsor for this project. The Municipality of Anchorage will participate in the cost-sharing and financing of this project in accordance with the draft Project Cooperation Agreement between the Department of the Army and the Municipality.

The cost estimate indicates that the fully funded cost for the project will be $5,342,000 (July 1997 dollars). The Federal Government will provide 65 percent of the cost of the general navigation features; the local sponsor will provide the remaining 35 percent, estimated at $1,870,000.

The Municipality has developed a financial plan which utilizes State of Alaska appropriations and funds from the Port of Anchorage reserves. A grant for half the required funds has been requested from the State Legislature and is expected to be available by July 1996. The balance of funds needed for the project is available from existing reserves available at the Port of Anchorage. Letters of support from the Alaska Department of Transportation and Public Facilities and the Municipality of Anchorage are attached to this document.

The financing plan submitted by the Municipality of Anchorage for financing the local sponsor's share of the project appears reasonable. The local sponsor appears to have the capability to finance its portion to the project.

Peter A. Topp
Colonel, Corps of Engineers
District Engineer

Municipality of Anchorage

P.O. Box 196650
Anchorage, Alaska 99519-6650
Telephone: (907) 343-4433

Rick Mystrom, Mayor

OFFICE OF THE MUNICIPAL MANAGER

RECEIVED

MAR 21 1996

REGULATORY FUNCTIONS BRANCH
Alaska District, Corps of Engineers

March 18, 1996

Colonel Peter A. Topp
District Engineer
U.S. Army Engineer District, Alaska
Post Office Box 898
Anchorage, Alaska 99506-0898

Dear Colonel Topp:

This letter has been coordinated with appropriate offices of the State of Alaska and expresses the intent of the Municipality of Anchorage (MOA) to cooperate with the Federal Government in initiating construction of the Knik Arm Shoal Channel. We understand that the MOA would be required to provide for the non-Federal share of the costs of construction of general navigation features as specified by Section 101 of the Water Resources Development Act of 1986 (Public Law 99-662). We further understand that the total project cost is estimated to be $5,342,000 and that the local sponsor or non-Federal share, based on the above law, will be 35 percent of the total cost.

We have reviewed a proposed draft Project Cooperation Agreement. The MOA is the organization empowered by law to provide the non-Federal cooperation required for the Navigation Improvement at Knik Arm Shoal, Cook Inlet, Alaska. We hereby inform you that it is our intent to enter into such an agreement if the harbor project is approved for construction by the Corps' Headquarters office.

We also understand that the MOA would be required to do the following:

a. Provide to the local share of project planning and construction cost;

b. Within the boundaries of the Municipality of Anchorage, hold and save the United States free from damages due to the construction and maintenance of the project, except damages due to the fault of negligence of the United States or its contractors.

We expect to receive a State grant of approximately 50% of the local match. The MOA will provide the other 50% from Port funds.

It is further understood that if this letter of intent is acceptable, you will recommend, in your capacity as District Engineer, that funds for the Federal share of the harbor be procured. In addition, we would request that this project be expeditiously coordinated during review processes so that earliest Federal funding opportunities can be explored.

Finally, the Municipality understands that this letter is merely a statement of intent on our part and not a binding contract.

Thank you for your anticipated courtesy and cooperation in this matter.

Sincerely,

Larry D. Crawford
Municipal Manager

TONY KNOWLES, GOVERNOR

3132 CHANNEL DRIVE
JUNEAU, ALASKA 99801-7898

TEXT :(907) 465-3652
FAX: (907) 586-8365
PHONE: (907) 465-3900

DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
OFFICE OF THE COMMISSIONER

March 11, 1996

Peter A. Topp, Colonel
District Engineer
Corps of Engineers
P.O. Box 898
Anchorage, AK 99506-0898

Dear Colonel Topp:

I have reviewed the report, Deep-draft Navigation Feasibility Report with Engineering Appendix, Cook Inlet, Alaska. The Department of Transportation and Public Facilities (DOT&PF) support the findings that it will provide a valuable added capability of a safe, 24 hour navigational approach to the Port of Anchorage facilities for deep draft tanker and cargo vessels at a reasonable cost. The project benefits the national economy and the people of Alaska.

The DOT&PF will continue to support this project in partnership with the Port of Anchorage, and is capable of financial participation, subject to availability of Corps Matching funds and legislative appropriation.

It is our request that the Alaska District continue to consider this project for a federal appropriation with construction to take place as soon as possible.

Sincerely,

Joseph L. Perkins

Joseph L. Perkins, P.E.
Commissioner

cc: Rick Mystom, Mayor, Municipality of Anchorage
Don Deitz, Director, Port of Anchorage, MOA

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

REPLY TO
ATTENTION OF

CEWES-CD-P (70)

4 August 1995

MEMORANDUM FOR Commander, U.S. Army Engineer District, Alaska,
ATTN: CENPA-EN-CW-PF (Mr. Orson Smith), P.O. Box 898,
Anchorage, AK 99506-0898

SUBJECT: Seasonal Current Surveys of Cook Inlet, Alaska with a Broadband Acoustic Doppler Current Profiler

1. Enclosed is a Memorandum For Record (MFR) detailing seasonal current surveys conducted at Cook Inlet, Alaska, in 1994 and subsequent data analyses. This work was performed for the Alaska District on MPIR number E86944030 and is in accordance with the Scope of Work dated 5 April 1994.

2. Please direct any questions or comments concerning this MFR to Ms. Terri L. Prickett at (601) 634-2337 or Mr. William L. Preslan at (601) 634-2020.

FOR THE DIRECTOR:

James R. Houston

Encl

JAMES R. HOUSTON, PhD
Director
Coastal Engineering Research Center

U.S. Department of Transportation

United States Coast Guard

Commander
Seventeenth Coast Guard District

P.O. Box 25517
Juneau, Alaska 99802-5517
Staff Symbol: oan
Phone: (907)463-2245

16540

JUL 25 1995

Dr. Orson Smith
U. S. Army Engineer District, Alaska
Civil Works Branch
P.O. Box 898
Anchorage, AK 99506-0898

Dear Dr. Smith:

As requested during your conversation with LT Rob Shaul last week, we have estimated a cost of $200,000 to realign the Fire Island Range in conjunction with your project to dredge Knik Arm Shoal.

We understand dredging is to begin in 1997. If the final project will require us to move the Fire Island Range, we need to know as soon as possible to plan the project and arrange funding.

Thank you for your assistance. My point of contact is LT Rob Shaul at 463-2249, or Petty Officer Adam Dixon at 463-2251.

Sincerely,

R. G. Seagrave

R. G. SEAGRAVE
Assistant Chief, Aids to Navigation & Waterways Management Branch
U. S. Coast Guard
By direction of the Commander

Sea-Land

Sea-Land Freight Service, Inc.
1717 Tidewater Road, P.O. Box 101939
Anchorage, Alaska 99510
907-274-2671

November 13, 1995

Dr. Orson P. Smith
Department of The Army
U. S. Army Engineer District, Alaska
P. O. Box 898
Anchorage, Alaska 99506-0898

Dr. Smith:

Sea-Land's Position to the "Deep Draft Navigation Feasibility Report" of September 1995:

Sea-Land Service Inc. is very enthusiastic with this plan of dealing with the Knik Arm Shoal, a major obstacle to the Port of Anchorage. This not only hampers Anchorage, but also the infrastructure of Alaska which the Port of Anchorage feeds. Discussions of this shoal restriction goes back to 1964 when Sea-Land vessels began calling the port.

The study shows a thorough look at the problem covering the environmental and geographical background, the past restriction placed on the Port and shipping, the look into the future for the demands of the region, and the resolution with this proposed dredging of the shoal.

Sea-Land Service Inc. presently has 3 (D-7s') specially constructed ships engaged in the Alaskan Trade. These vessel were Sea-Land's commitment to Alaska and it's people when the original C-4's calling Alaska were retired after their 23 years of service. The D-7's came on scene in 1987 to provide service to the ports of Anchorage, Kodiak, and Dutch Harbor. The D-7's were built with the following characteristics: Length overall 216.4 M. ,a beam of 23.8 M , deep draft of 9.7M, and a service speed of 19.2 kts.

As indicated previously , Sea-Land is optimistic about this plan to remove a portion of the shoal. The proposed action, however is based on a study which states; " A channel width of 180 M allows safe navigation in icy winter conditions. An additional 30m on either side would be excavated, for a total width of 240 M as allowance for uncertainties in the analysis of the channel stability." This statement is flawed, it states that a channel of 240 M is going to give a safe working and navigational area for ships transiting Cook Inlet. As the study Indicates Cook Inlet has a uniqueness when one considers the major tidal changes, the winter ice flows, and the visibility reduction experience a significant part of the year. Arrival and departures are often accomplished under marginal weather and visibility conditions and when trying to maneuver in heavy ice , the passage is made even more difficult by a narrow channel. To elaborate a little further I provide the following:

1.Tidal action in Knik Arm: The tide comes and goes twice daily with the average tidal range of some 28 ft. and currents which average 4 knots or better. The ship's on approach to the port have to turn cross-currents (at reduced speed) to maintain positioning in the deeper channels.

2. Ice Conditions : Ice at the Port of Anchorage begins in November and ends in early April . During these months ships experience Ice Pans at the Port that can be two to three feet thick , or more , and larger than a football field. The maneuverability of large vessels at slow speeds into the port of Anchorage is progressively more restricted as ice density increases. Entering and departing the Port of Anchorage under such conditions becomes a most formidable task.

3. Winds have a major surface affect against the ships and the water. T he prevailing winds are from the North and the North East during low water periods almost 90 % of the time .

Sea-Land vessels are 216.4 M in length and in the event one of our vessels gets cross-wise to the channel (240 M width) there is not sufficient enough room to maneuver or navigate. Like Tote, Sea-Land favors a channel width of 305 M. or better. This dimension gives adequate room to content with : cross currents, wind , wave action, bank suction/cushion, limited visibility, ice, and allows a margin for compensation.

Sea-land vessels presently operate the D-7's with a deep draft of 9.8 M and we have had discussions of utilizing larger vessels which could draw as much as 10.9 M . In light of this and the prospects of Anchorage attracting larger vessels in the year 2000, we encourage that the controlling depth at MLLW be increased to 14 M , (see the attachments).

These desired changes : increasing the width to 305M, and having the channel's controlling depth of 14 m,at MLLW. give Sea-Land the expectation that savings will be realized. The removal of this obstruction will positively affect the vessels fuel efficiency, the stevedore cost in Anchorage and Tacoma , the cost erfective repair cost, and improve the schedule integrity . Sea-Land's 30 years of exoerience in calling the Port of Anchorage and the future demands which will be placed on the Port, well justify these project increases.

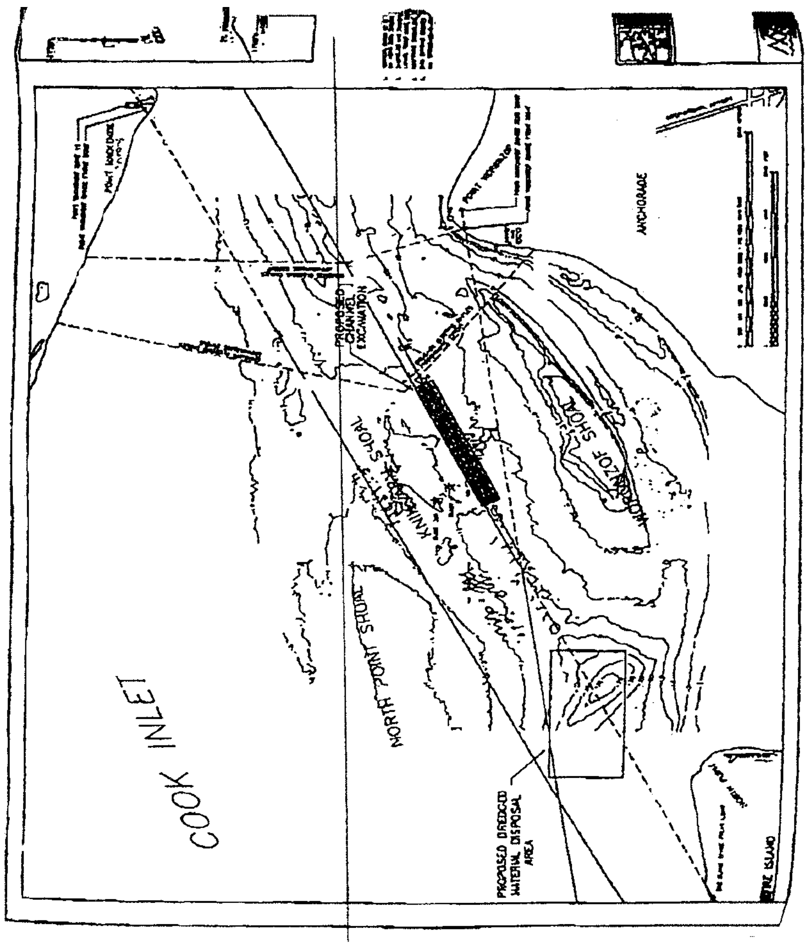
Providing a channel with these increased dimensions allows vessels' a reasonable transit and ensures channel stability.

In summary, the purpose of the shoal removal is to increase efficient trade to the region, to improve schedule integrity of vessel calls, to assist in enhancing vessel and cargo operations by removing the tidal window as an obstacle. Limiting the channel to 240 M width and a controlling depth of 13.5 M at MLLW fails to meet these goals.

Sea-Land is an avid supporter of this project and praises the efforts the Army Corp. of Engineers, the State of Alaska , the City and Port of Anchorage in this undertaking. We thank you for this opportunity to participate in this review process, which will mutually benefit the State of Alaska and the shipoing industry.

dbb
attachments

cc: Tacoma - J.V. Keenan - SMS
- R.J.Satava - SMS


COOK INLET
NORTH POINT SHOAL
KNIK ARM SHOAL
WORONZOF SHOAL
PROPOSED CHANNEL EXCAVATION
PROPOSED DREDGED MATERIAL DISPOSAL AREA
ANCHORAGE

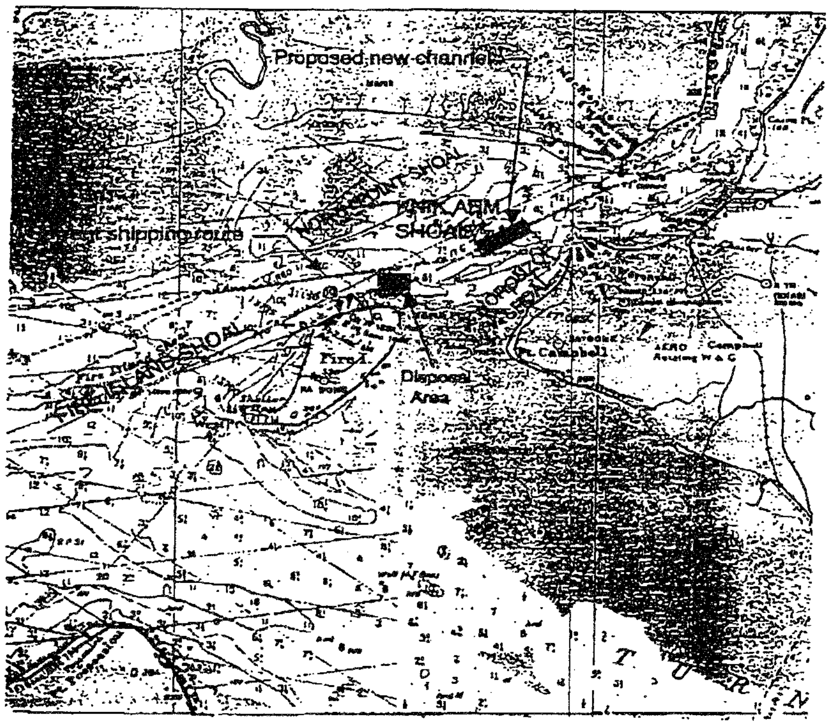
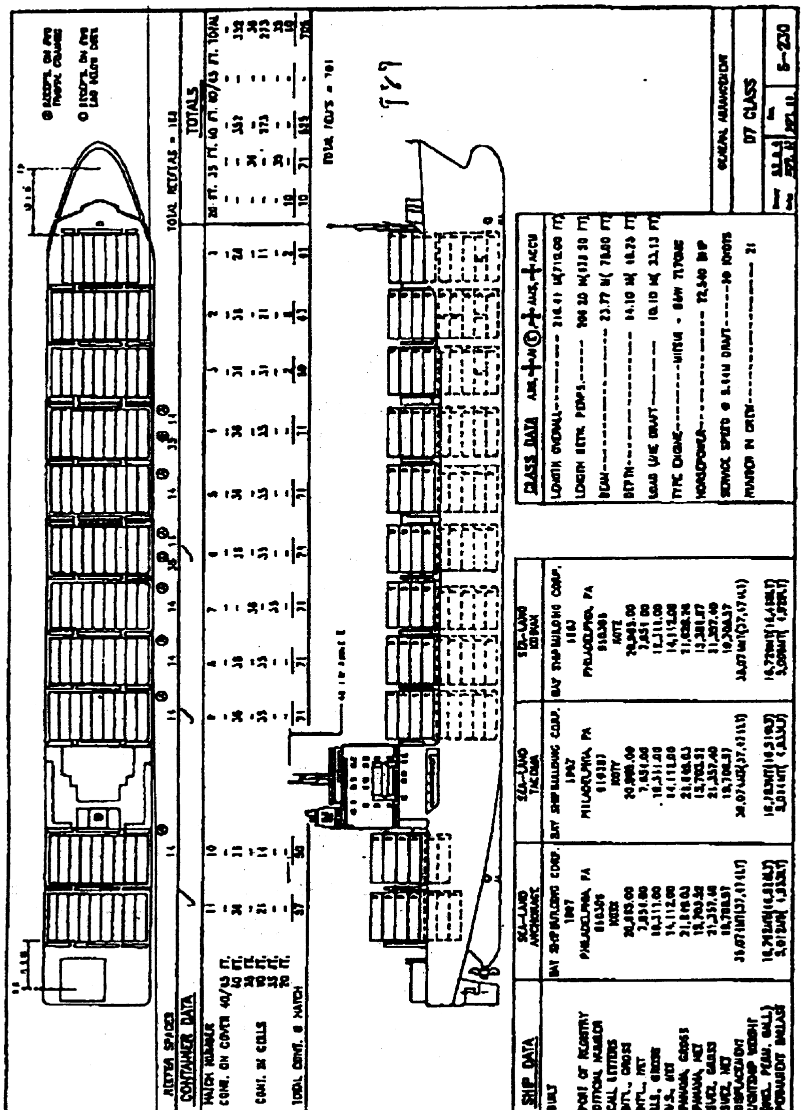
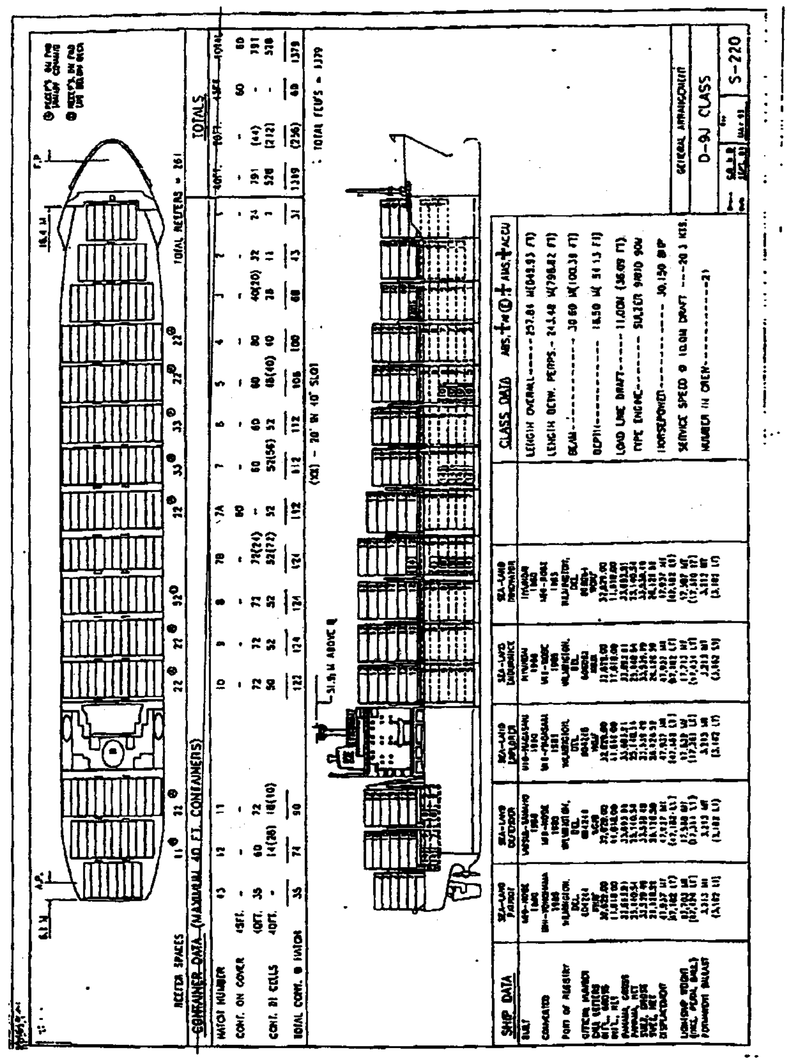


FIGURE 6-1.—Current shipping area in upper Cook Inlet, with proposed channel and disposal area locations.

of the surveys compared (1978 - 1994) in figure A-3, maintenance dredging of a quantity less than 50 percent of that for the initial excavation does not appear to be necessary more than every 5 years. A sensitivity analysis shows that maintenance dredging of 50 percent of the initial excavation quantity at 25 years and at 5 years results in the same optimum channel depth of -13.5 m MLLW, including 1.5 m for dredging tolerance and shoaling. These findings are discussed in more detail in Appendix A, Channel Design.




CONTAINER DATA (MAXIMUM 40 FT. CONTAINERS)
TOTALS
SHIP DATA
CLASS DATA
GENERAL ARRANGEMENT
D-9J CLASS
S-220

CHUGACH ELECTRIC
ASSOCIATION, INC.

November 10, 1995

Via Fax Line: (907) 753-2625
(Hardcopy to follow.)

Department of the Army
U.S. Army Engineer District, Alaska
P.O. Box 898
Anchorage, Alaska 99506-0898

Attention: Mr. Orson P. Smith, P.E.

Subject: Cook Inlet Alaska - Deep Draft Navigation, Feasibility Report

Dear Mr. Smith:

We would like to thank you for making a copy of subject report available to us for review and the opportunity to provide comments at the public and special interest meetings.

This letter will summarize Chugach's concerns as brought forward in those meetings. These concerns are primarily related to activities in the vicinity of its submarine cable field between Point Woronzof and Point MacKenzie. Our records indicate that many cable failures or damage occurred while work was being performed in the field or close by. Several incidences of ships' anchors have also been recorded.

While the plans provided show that the area to be dredged does not extend into the cable field, we caution that inadvertent intrusion appears possible due to tidal currents or equipment misoperation. It is noted that the cable closest to the project area will be marked with buoys while dredging is in progress and we support this effort. It needs to be clearly understood by the operators that repair or replacement of a damaged high voltage cable costs around $6,000,000 to $8,000,000.

We understand the desire for a deeper shipping channel across the Knik Arm shoal, but request that the channel depth be limited to not be greater than the depth across the cable field to reduce the risk passing traffic making contact with the cables. All cables have been placed on the sea floor and do not have protective covers.

5601 Minnesota Drive • P.O. Box 196300 • Anchorage, Alaska 99519-6300
Phone 907-563-7494 • FAX 907-562-0027

We again appreciate the opportunity to provide input to the project activities at this early stage and are looking forward to work with you, when field activities begin. If you have any questions please, call me at 762-4626.

Sincerely,

CHUGACH ELECTRIC ASSOCIATION, INC.

Dora L. Gropp

Dora L. Gropp
Manager, Transmission & Special Projects

DLG/ahw
c:\wpwin60\wpdocs\dlg\corps.wpd

Enclosures

cc: Michael Massin
Dave Braun
Victor Montemezzani
File "138kV Submarine Cables"
RF

SOUTHWEST ALASKA PILOTS ASSOCIATION

P.O. Box 977
Homer, Alaska 99603

(907) 235-8783
Fax (907) 235-6119

November 10, 1995

Dr. Orson P. Smith
Department of the Army
U.S. Army Engineer District, Alaska
P.O. Box 898
Anchorage, Alaska 99506-0898

Dear Dr. Smith:

After reviewing the Deep-Draft Navigation Feasibility Report and especially the section on pertinent data, I am compelled to comment on the specifics of the channel width through Knik Arm Shoal.

The proposed width of 220 meters should be increased to a width of 304 meters as suggested by Captain M.J. Kucharski, Master of the *S.S. WESTERN VENTURE*. I agree with the comments of Captain Kucharski in his letter dated October 24, 1995. Furthermore, our association pilots a variety of vessels to the Port of Anchorage, among these being oil tankers, bulk carriers and passenger vessels. The oil tankers and bulk carriers are relatively under powered comparatively to the container and ro-ro ships on the liner service to Anchorage. They also have a more blunt bow. This being the case, during the heavy ice months we experience more resistance to our passage due to the ice. Often the vessel is unable to proceed directly along the desired track line. The vessel's heading may take a sheer of up to thirty degrees when trying to break through a particularly large ice pan. If this were to occur in the proposed dredged channel, then conceivably before the pilot was able to straighten out the vessel's heading, the vessel would be aground. I envision that if the channel were to be dredged as indicated then the proposed time savings would not be realized by the vessels which we pilot during the winter. The reason being we would deem it more prudent to wait for higher water to allow us a greater margin of error if we were unable to stay within the channel.

We are grateful for this opportunity to comment on this important issue.

Sincerely,

Captain Eric Eliassen
by CRC

Captain Eric Eliassen
President

ERE/crc

TOTEM OCEAN TRAILER EXPRESS, INC.
2511 TIDEWATER ROAD • ANCHORAGE, ALASKA 99501
PHONE (907) 276-5868 • ADM FAX (907) 278-0461

November 7, 1995

Department of the Army
U.S. Army Engineer District, Alaska
P. O. Box 898
Anchorage, Alaska 00506-0000

ATTN.: Mr. Orson Smith, PE, Ph.D.
Project Formulation Section

Dear Mr. Smith:

I have reviewed the Deep Draft Navigation Feasibility Report dated September 1995. This is a well written and developed study. I circulated the report to the Masters and Cook Inlet Pilots that navigate the TOTE vessels in Cook Inlet, I will attach their comments for your perusal.

Totem's Masters and Pilots are extremely experienced and skilled navigating within Cook Inlet in all types of weather conditions, their comments should be very helpful in making decisions that will determine the final design of the channel.

The major concern with the channel as designed in the feasibility study is the width of the channel, 220 meters, versus the original design of 300 meters. This was agreed on at a meeting in Portland, Oregon when our then Vice President of Marine Operation Bob Magee, and Andy Wardell our most experienced Cook Inlet Pilot attended the Corps District hearings.

The comments the officers made are related to the safety factor of entering the dredged channel in adverse weather such as blinding snow, heavy winds, currents, and navigational error due to radar "fixes" and their accuracy.

I would like to think that after reading their concerns we can have a discussion centered around the issues on both the November 9, 1995 meeting at the Port of Anchorage, and the November 15 meeting at the Corps of Engineers.

Very truly yours,

Ted DeBoer
Alaska Operations Manager

TDB/skr

Attach.

S.S. GREAT LAND
NOVEMBER 5, 1995

TO: Mr. Ted DeBoer
FM: Capt. J.N. Hearn

Subj: Deep-Draft Navigation Feasibility Report
Cook Inlet, Alaska

I have been asked by Rich Griffith to review this report and submit my comments to your attention. With my report, I am delivering several other reports from TOTE Captains and also, your copy of the feasibility report.

This is a well written and developed study. I have learned a great deal about Cook Inlet from the report. The following are my comments:

1) CHANNEL WIDTH

There is a great deal of attention toward the channel width. This is probably the most important consideration other than the actual depth. It must be recognized that ship navigators will make their sole judgement on use of the channel on each transit of Knik Arm only when considering all factors. These factors include adverse weather conditions, tide height and current conditions, vessel characteristics, etc. Improvements to channel depth and width only increase the allowances for transit of the shoal.

Marginal improvements to channel width that do not impress the ship navigators as sufficiently safe will become small considerations. At present, the shallowest area of the channel is the controlling depth of the shoal. The channel width is not a major factor as it is large enough for crabbing during adverse wind and current conditions. Due to inherent margins of error in navigation systems, the whole channel is expected to be used and this will probably always be the case during these adverse conditions. Thus, during adverse and winter conditions, the controlling depth shall remain the shallowest location of the ENTIRE navigable area, not just the defined channel along the rangeline.

My point is that the channel width must remain wide enough for the navigating officers to consider worthwhile. I can see that all navigators recommend the width to remain at 1,000 feet. If this is not done then the project is of considerably lesser value due to that fact that the improvement will not be used by the ship navigators.

2) IMPROVED AIDS TO NAVIGATION

The controlling factor to channel width is the accuracy whereby the navigator must maintain the ship within the channel. I have read that several aids shall be incorporated to improve navigation in the vicinity of Knik Arm Shoal. The differential GPS and the ECDIS (electronic chart display) shall become important factors in using the 1,000 foot channel. Navigators shall trust the reliability of these systems after proven accuracy during safe transits. I strongly recommend that these improvements be aggresively pursued to coincide with the channel improvements.

I would like to further suggest the addition of channel marking buoys during the summer months on both sides of the channel. Regardless of the feasibility study's documentation, there is two way traffic on the shoal with deep draft traffic and smaller vessels. This occurs with some frequency during the summer months of heavier congestion within the port area. A well marked channel shall improve use of the navigable area and shall also provide aids to vessels without a DGPS or ECDIS navigation system.

Thank you for the opportunity to review and comment on this study. I remain interested and would be happy to assist in any other way.

Yours truly,

Jack Hearn

Captain Jack Hearn
Master, S.S. Great Land

cc: Mr. R. Griffith

S.S. NORTHERN LIGHTS
October 28,1995

To: Mr. Richard Griffith
TOTE V.P. Vessel Operations

FROM: William Roffey Pilot

SUBJECT: Request for comments concerning the Knik Arm Shoal Project in Anchorage.

Dear Sir,

After reviewing the proposal for the dredging of a channel at Knik Arm Shoal, I feel my main concern is the width of the channel at about 722 feet. Approaching the channel inbbund on the Woronzof Range on a course of 081 degrees a vessel turns into the channel to a 062 degree course. The buoys marking the shoal are seasonal and the Fire Island Range is astern after comming to 062 course. The channel itself will make the turn more critical because of the new width of the channel. A vessel may also experience bank cushon along with the effects of wind,tidal current and ice in the winter, making it more difficult to maintain the heading and compensating for the set of the vessel. If possible my recommendation would be for the removal of the shoal area not just a channel cut across it and that the channel be about 1200 feet wide. In addition a range could possibly be put on Cairn Point to assist in transiting the new channel.

Sincerely

William T. Roffey

William T. Roffey Pilot

10/27/95

Dear Mr. Griffith:

On account of limited time, I have read all the highlights pages only.

My opinion, a 300M wide with 12M deep at low tide is the minimum requirement.

This channel is not like one in the river with mud bottom which will cause less damage if a ship goes aground. This is rocky bottom channel once touched; will make holes easily. Therefore 300M wide is the minimum.

With best regards

Sincerely

[illegible]

24 October 1995

From: Captain M.J. Kucharski, Master, S.S. Westward Venture
To : Mr. T. Deboer, Alaska Operations Manager, TOTE
Subj : Deep Draft Navigation Feasibility Report
Encl : (1)

Dear Ted,

I am in receipt of and have reviewed said report. I am in basic agreement with said report. The only part I find major exception to is the proposed channel width. It is not the width that Captain Wardell and I had recommended when asked for our opinions. We had asked for a minimum width of 1,000 ft (304 meters.) The proposed channel width is 240 meters. If this is what they are willing to dredge, then so be it. However, keep in mind that there will be times that we may deem it unsafe to enter. This would most likely occur during high wind situations with reduced visibility (usually driving snow.)

I call to your attention chapter 6, section 6.5.2 entitled "Channel Width" with further amplification in Appendix A, Section 2, page A-4. By their own admission, radar fixes can have an accuracy of between 100-150 meters of true position. Couple with this half the width of the vessel (approx. 14 meters) and the added width (approx. 21 meters) for a 5 degree "crab" which, I might add, is not unusual during high wind situations and you get a total of a minimum of 185 meters needed (see the enclosed diagram for amplification.) Their proposed width is 240 meters. 240 meters less 185 (150+14+21) meters is 55 meters. This must be then divided in half because you have no easy way of determining your precise position off **center line** if you are steering to a range or are setting up on the centerline of the channel.. You thereby have 55 meters/2 or 27.5 meters breathing room. This is a slim margin for a vessel navigating in reduced visibility during a high wind situation. Keep in mind that we don't have the luxury of stopping (we often cross at speeds in excess of 15 knots - for ship control purposes) to determine a more accurate assessment of our position or the situation. I have entered port in buoyed channels on VLCC's that had to await high tide for transit. This was done with less than five feet beneath the keel. But in those cases we were able to operate at less than five knots, visibility was excellent and we had numerous tugs to assist. In short, under the conditions we operate under, they are affording us very little margin for error.

In the study on page 60, section 6.5.2, paragraph two, line two, it is stated that "this width is conservative in terms of major marine fairways around the world." However, the conditions in and around Anchorage are some of the most severe in the world. There have been numerous times when we have crossed the shoal in high wind conditions (over 50 kts.) and have had to use more than 5 degrees of leeway to keep the vessel on track. This is termed "crabbing." To reduce this crab, more speed is usually the solution. However, a slight miscalculation (keeping in mind the 27.5 meters mentioned above) can lead to disaster because of the increased speed needed to offset said crab. If you slow down, the crab is more pronounced and the clearance is less. Another item worth noting is that when you increase speed to offset a "crab", parallel sinkage and squat are greater. Without getting too technical (the scientists will know exactly what I am talking about) the former is due to the "Bernoulli" or "Venturi" principles and the latter is due to the vessel getting "in synch" with the high and low pressure patterns caused by the higher pressure set up on the bow and low pressure set up forward of the propeller. The main point is that these conditions cause loss of ship control. The way to reduce them is to slow down. However, this will only increase "crabbing" as mentioned above. Increased "crabbing" only reduces your margin for safety.

In closing, I hope that the above clearly explains that our recommendation for a 1,000 foot channel is not a "wish list" request. The down side to a narrower channel is that, with gangs and tug waiting, we may not cross the shoal at the appointed time. For a much more useable channel, I strongly recommend that we petition the Army Corps of Engineers to dredge to a width of 1,000 feet (304 meters.)

Thank you for the chance to review and comment on the study. It was extremely interesting reading.

Sincerely,

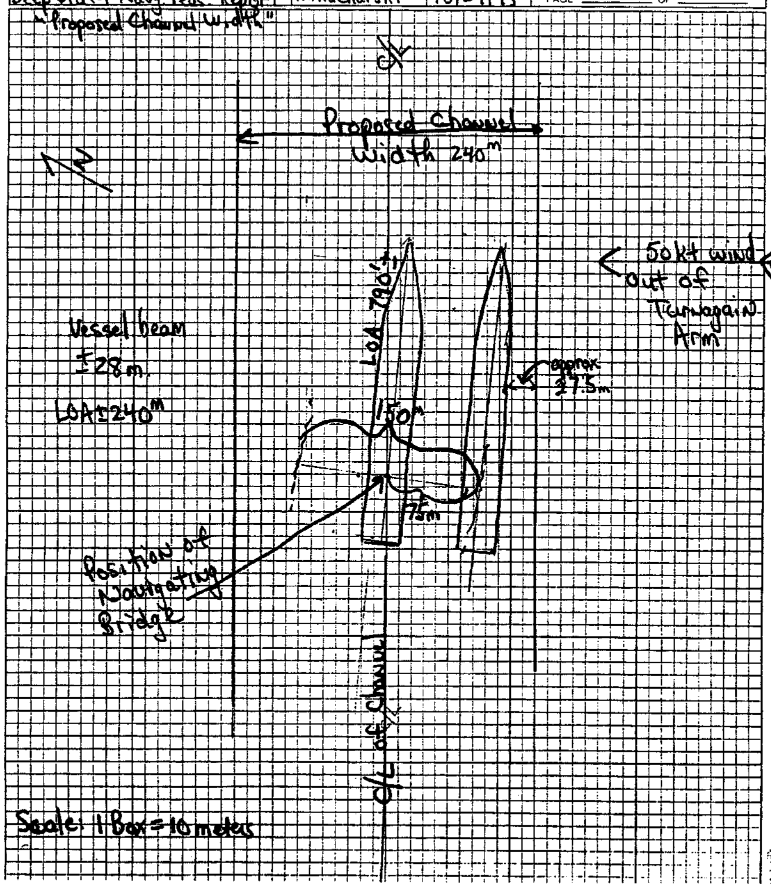
MKucharski

Captain M.J. Kucharski

cc: Mr. R. Griffith

TOTEM OCEAN TRAILER EXPRESS, INC.
MARINE OPERATIONS DIVISION
PROJECT REPORT
500 ALEXANDER AVENUE • TACOMA, WASHINGTON 98421 • TELEX 510-600-4900 TOTE TAC
WATS OUTSIDE WA 1-800-426-0074 • WATS INSIDE WA 1-800-552-7726 • FAX (206) 756-9218

TO: T. Deboer	SUBJECT: Enclosure to Letter Dated 10/24/95		
PROJECT: Deep Draft Navg. Feas. Report	PREPARED BY: M. Kucharski	DATE: 10/24/95	PAGE ____ OF ____



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

REPLY TO
ATTENTION OF

CEWES-CD-P (340) 4 August 1995

MEMORANDUM FOR RECORD

SUBJECT: Seasonal Current Surveys of Cook Inlet, Alaska with a Broadband Acoustic Doppler Current Profiler

INTRODUCTION

1. This memorandum summarizes principal activities that took place in Cook Inlet, AK, during a series of three current surveys conducted in May, July, October, 1994, and provides discussion and results from subsequent data analyses. The objective of the surveys was to collect seasonal current data during mid-ebb and mid-flood tides in support of Alaska District (NPA) monitoring activities in the vicinity of the Knik Arm Shoal located in Cook Inlet. A fourth current survey was attempted in November, 1994, but ice in the inlet prevented data collection. This work was performed by the Coastal Engineering Research Center (CERC), Prototype Measurement and Analysis Branch (PMAB) for the Alaska District on MPIR number E86944030 and in accordance with the Scope of Work dated 5 April 1994.

SURVEY DESCRIPTIONS

2. For the May, October, and November surveys, NPA provided a contract survey vessel equipped with a Differential Global Positioning System (DGPS) receiver and a hydrographic survey package for plotting survey ranges. SEXTANT, a software package was used for hydrographic survey data collection. During the July data collection effort, a DGPS was not available, and a standard GPS was used for positioning. For all surveys, a 600-kHz Broad-band Acoustic Doppler Current Profiler (BBADCP) was used to collect current data. The BBADCP was connected to a data acquisition system located in the cabin of the survey vessel and interfaced with the DGPS. The BBADCP head was deployed from a mount located on the starboard side of the vessel during the May and October surveys and from the bow during the July survey. The BBADCP was lowered to approximately 60 to 80 cm below the water surface.

ROUTING:
1. CEWES-CD-P (Mr. W. L. ~~Preslan~~) WP
2. CEWES-CD (Mr. T. W. Richardson)
3. CEWES-CV-A (Mr. C. C. Calhoun) C 8/8
4. CEWES-CV-Z (Dr. J. R. Houston)
5.
6. CEWES-CD-P (Mr. T. L. Prickett)
7. CEWES-CD-P (Ms. Davenport, files)

3. Survey ranges were designated by NPA and are referred to as L1, L6, L7, L8, L9, and L10. The locations of the designated survey ranges are provided in Figure 1. L1 was approximately 3.5 miles in length and oriented along the inlet in the northeast to southwest direction, parallel to the tidal flow. All other ranges were approximately 1.8 miles in length and oriented perpendicular to L1, across the inlet. Distance between the shorter ranges was approximately 0.8 miles. Just before the survey vessel was in position to start the current survey, the BBADCP was lowered into the water and data collection initiated. Typical ship speed during each range survey ranged from 1 to 2 knots. The BBADCP was hoisted out of the water and secured during transit to and from the project site and between survey ranges.

4. The spring survey was originally scheduled to take place during the spring tide the week of 25 April, but the survey was delayed for 1 week because of ice in the inlet. Data collection for the spring survey occurred on May 4, with the BBADCP deployed off the starboard side of the survey vessel, approximately amidship. Wave conditions in the inlet were relatively calm in the morning but picked up to approximately 2 ft waves in the late afternoon. Ranges L6, L8, and L10 were surveyed during both mid-ebb and flood tides. Range L1 was surveyed only during flood tide.

5. The summer survey occurred on 13-14 July. Wave conditions in the inlet were calm in the morning and became choppy late in the afternoon. A different vessel was used for this survey, and the BBADCP sensor was mounted off the bow. Ranges L1, L7, L8, and L9 were surveyed on 13 July during ebb tide and then surveyed again during flood tide on 14 July. A substantial amount of suspended sediment was visually and acoustically observed in the water column. The large amount of suspended sediment may have contributed to problems experienced with the bottom tracking at times.

6. The fall survey occurred on 5 October. Wave conditions were choppy during this survey. The same vessel used in the May survey was used during this survey, and the BBADCP was deployed off the starboard side of the vessel. Ranges L6, L8, and L10 were surveyed during both mid-ebb and flood tides. Range L1 was surveyed only during flood tide.

7. The winter survey was scheduled for the week of 28 November. The survey took place aboard the *Pacific Wind*, a tug with ice-breaking capabilities. Ice up to 8-in. thick covered the survey area. The mount designed to protect the BBADCP sensors from ice damage appeared inadequate for this thickness of ice, so the BBADCP was not deployed, and no acoustic data were collected.

DATA ANALYSIS

8. During data collection, for each transect across a range, three data files were collected containing: raw BBADCP data without navigation input, raw navigation data that were being output by the DGPS or GPS, and BBADCP data with the processed navigation information. For this study the files containing the BBADCP data along with the processed navigation data were used in all subsequent data processing. All data files were provided to NPA following each survey.

9. As the vessel proceeded across each range, the BBADCP measured water velocity in a series of 100-cm-thick depth cells (bins) that cover almost the entire water column from near the surface to near the bottom approximately every four seconds. The water velocity measured in each bin represents the average water velocity based on measurements along all 4 beams. A vertical profile of water velocity was collected every four seconds and is referred to as an ensemble. The first bin in an ensemble starts approximately 50-60 cm below the head of the BBADCP, and the last bin ends at a distance above the bottom approximately equal to 15 percent of the water depth. Since the head of the BBADCP was mounted approximately 80 cm below the water surface, the first velocity measurement is at an approximate depth of 1.4 m. Because of these limitations a layer of water near the surface and near the bottom is present in which no velocity measurements are made. These "blank" layers should be considered during any data analysis.

10. The BBADCP measures the velocity of the water relative to itself. Therefore, if the BBADCP is on a moving vessel, the BBADCP is measuring the velocity of the water relative to the vessel. In order to obtain the water velocity in earth coordinates, it is necessary to remove the vessel's velocity from the relative water velocity measured by the BBADCP. This requires accurate information on the vessel's velocity. Two approaches for determining the vessel's velocity are described below.

11. The BBADCP alternates between sending out acoustic signals to measure the velocity of the water relative to the vessel and to measure the vessel's velocity relative to the bottom. Using the acoustic signals to measure the vessel's velocity is referred to as bottom tracking and under most conditions is quite accurate. The second method of determining the vessel's velocity is from an external navigation device such as DGPS. During the May and October surveys, the bottom tracking performed very well and was used to determine the vessel's velocity. The DGPS was used only for positioning. During the July survey, there were periods when the BBADCP lost bottom tracking because of the high flow velocities and considerable suspended sediment. Because DGPS was not used and the GPS data were not sufficiently accurate, it was not possible to determine the ship's velocity during the periods with no bottom tracking. Therefore, the data could not be processed during those periods to determine water velocity.

12. Spatial positioning of the ensembles is dependent on the vessel's velocity because the BBADCP sampling is time controlled and not space controlled. During data collection, vessel velocity is not always consistent, resulting in a variable spacing of ensembles across the channel. Ensemble spacing is further complicated by the difficulty associated with steering the vessel along the same track line for each transect. Spacing and deviations in the vessel's track are illustrated in Figure 2.

13. Variability in ensemble spacing makes it difficult to compare one transect to the next without putting the ensembles into a common spatial frame of reference. To put each transect into a common frame of reference, an "ideal" line is chosen for each of the ranges which represents a straight line between the start and stop positions for the range. The locations of the ensembles are projected onto this straight line. The ensemble positions are projected by determining where a line that is perpendicular to the ideal line and intersects the ensemble positions would intersect the ideal line. Figure 2 illustrates the projection of the ensembles' actual position onto the ideal line. In this manner each of the ensembles can be referenced to their position along this ideal line within the inlet. An assumption is made that the velocity structure within the inlet does not vary much over short distance along lines parallel and perpendicular to the axis of the channel. Once the data have been projected onto the ideal line, it is possible to generate a complete profile of the velocity structure across the study area. Because the data from the different transects for each range have been put into a common reference frame, it is possible to compare the velocity profiles from transect to transect and assess how the velocity structure across the channel changes.

14. The BBADCP determines current direction using an internal compass. Readings from the compass must be adjusted to take local magnetic deviations into account. A magnetic declination of 24.5 degrees east is present in the Cook Inlet project area. Once this correction was included in the data processing, a comparison was made between the vessel's position based on bottom track and the vessel's position based on DGPS when it was available to determine compass offsets. Observed compass offsets for each survey were the basis for adjustments during data processing. During the May survey, a constant offset of 6 degrees was observed and during the July survey only a minor offset of about 3 degrees was observed. For the October survey, it was necessary to adjust each range separately based on a comparison between bottom track and DGPS position. In every case though, the adjustment was small.

15. Data plots. The data collected during this study are shown in 3 types of plots for each transect. Figure 3 shows an example of stick plots of current vectors for different depths. The solid line indicates the ship track as seen from above. Lines coming off the shiptrack are velocity vectors for the currents measured at the noted depth. The length of the vector is directly related to the magnitude of the current and points in the direction of the current. This plot is useful in getting a feel for the current velocities in a data set.

16. The other plots are referenced to the ideal line and the location of the profiles along the ideal line. Figure 4 is an example of a contour plot of the velocity structure as if a slice had been taken across the inlet and was being viewed from the side. The depth-axis on these plots indicates the depth of the bins. The velocity data were also depth-averaged across each transect, and an example is shown in Figure 5. A set of the plots described above was generated for each transect. Plots for all transects from the spring, summer, and fall surveys have already been provided to NPA.

17. General observations from all surveys:

Range L1, that ran along the inlet, exhibited high velocities (100 to 200 cm/sec) almost completely through the water column during flood tide. Velocities of greatest magnitude (200 to 280 cm/sec) occurred over the Knik Arm Shoal. During the July survey (in which both ebb and flood tide were surveyed), a similar range of velocities was observed for both the ebb and flood tide.

In Ranges L6 through L10, which ran across the inlet, high velocities were observed during both ebb and flood in the vicinity of the Knik Arm Shoal (the center portion of the transects). Decreasing velocities (140 to 0 cm/sec) were observed at the shallower north and south ends of the transect. During periods of peak flow, high velocities (140 to 280 cm/sec) were observed almost completely through the water column above the shoal.

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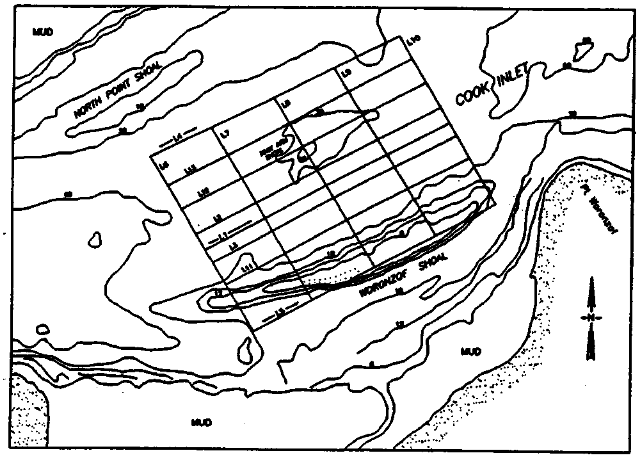

Figure 1. Location of Cook Inlet survey range lines

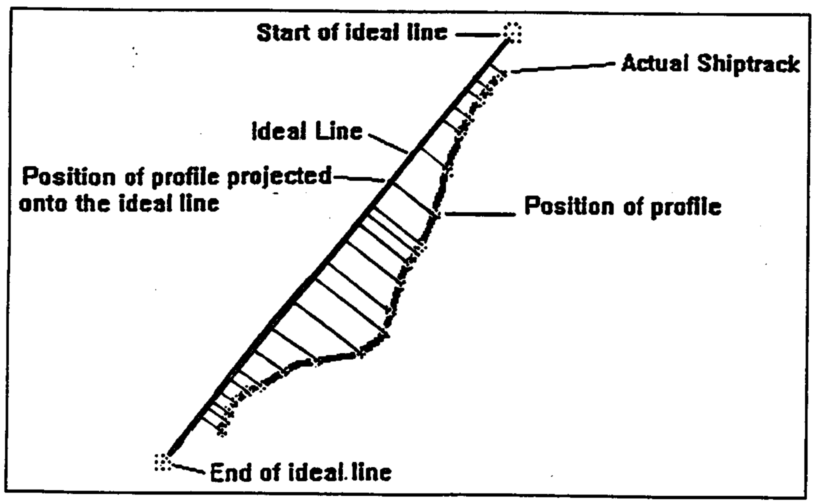

Figure 2. Ship's track and ensemble position. Projection of ensemble positions onto the ideal line.

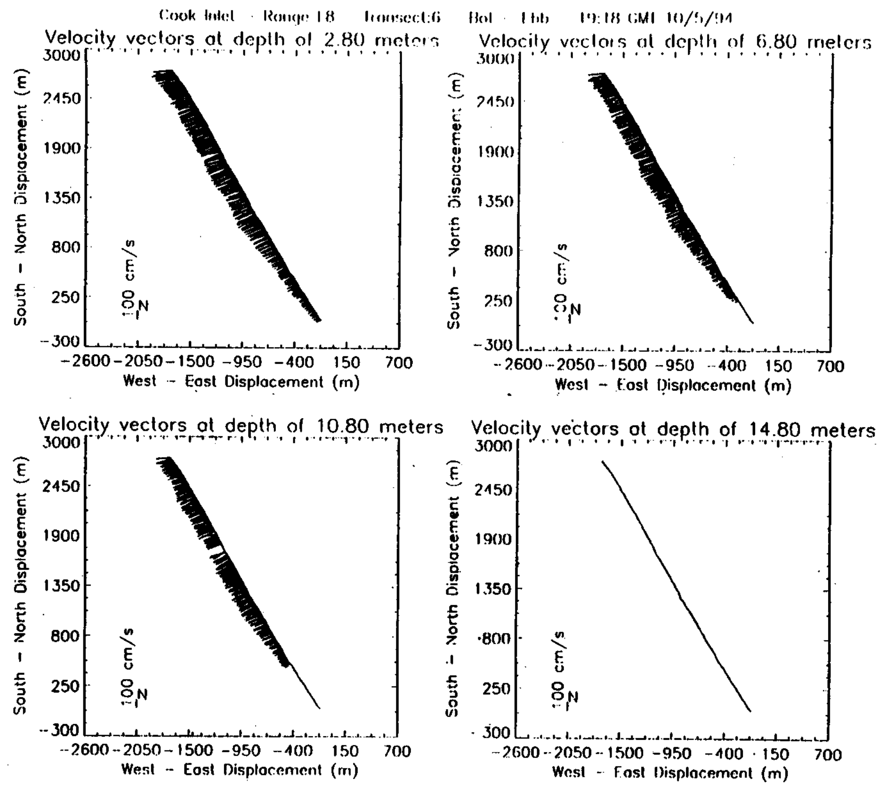

Figure 3. Stick plot showing velocity vectors along ship track

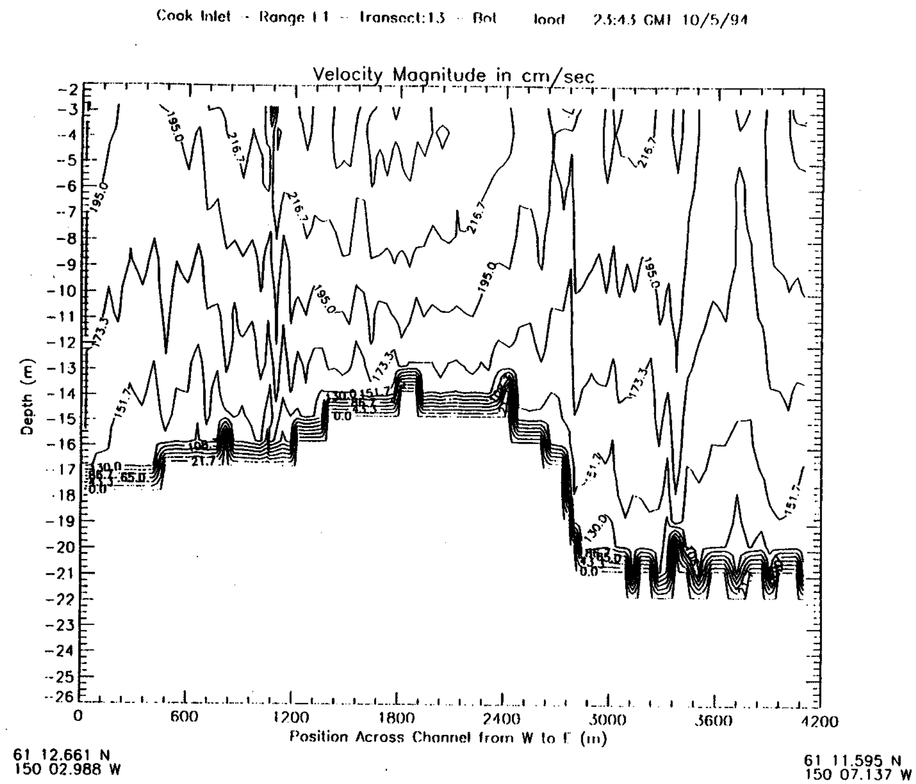

Figure 4. Example contour plot of current velocities

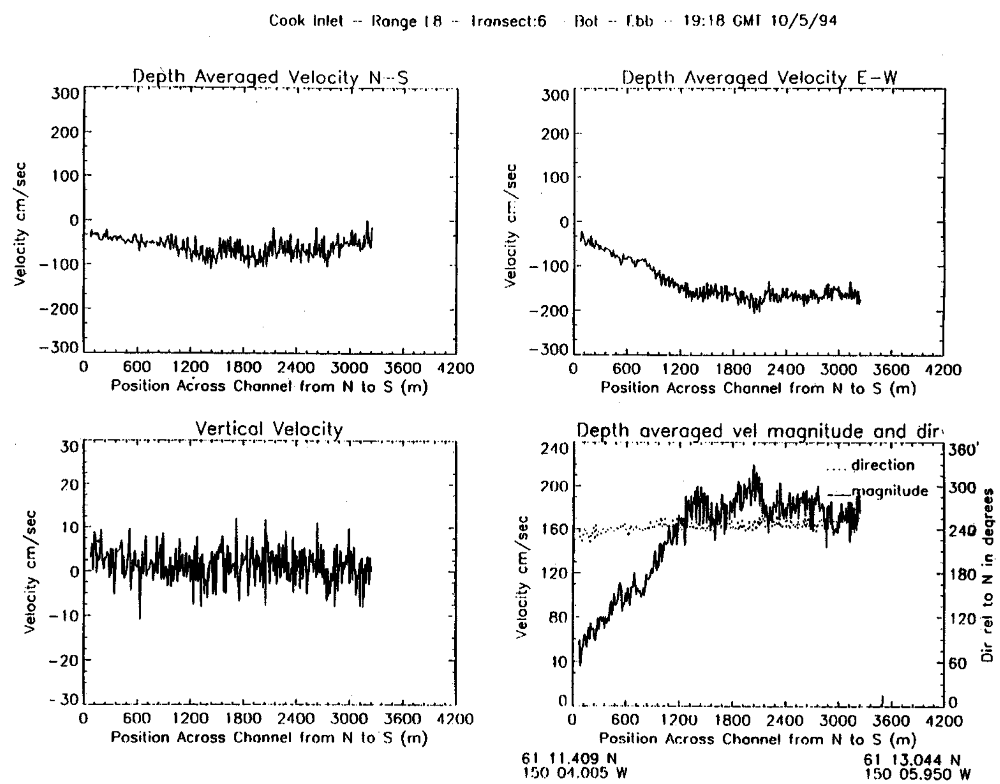

Figure 5. Example of depth-averaged velocity data across transect